HANDBOOK

FOR

HIGHWAY ENGINEERS

CONTAINING INFORMATION
ORDINARILY USED IN THE DESIGN AND CONSTRUCTION OF ROADS WARRANTING AN EXPENDITURE
OF $5,000 TO $30,000 PER MILE

PART I. Principles of Design
PART II. Practice of Design and Construction

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PREFACE

The purpose of this book is to collect, in a compact and convenient form, information ordinarily required in the field and office practice of road design and construction.

The book is designed to meet the requirements of both experienced and inexperienced road men. The material on the relative importance of the different parts of the design, and the possibilities of economy, without impairing the efficiency of the road, are primarily for the inexperienced engineer. The collection of cost data and the tables will be useful to any one engaged in road work.

As it is difficult to avoid clerical errors and mistakes in proofreading in first editions, we shall appreciate the coöperation of readers in calling our attention to any errors.

W. G. H.
E. A. B.

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HANDBOOK FOR HIGHWAY ENGINEERS

PART I. THEORY OF DESIGN

INTRODUCTORY

THE necessity for the permanent improvement of the main country roads has been so well recognized by all the States that the work promises in a few years to equal in magnitude that of Railroad, Canal, and River transportation.

Highway construction has increased so rapidly that there are not enough experienced engineers to handle it. Most of the departments have been forced to use untrained men and have tried to make their plans "fool-proof" by standardizing the designs in detail. Road work is peculiarly unfitted for such treatment, as an appropriate and economical design often calls for changes every 100 feet and too much Standardization has resulted in a waste of money and unsatisfactory plans.

The general public still believes that the work requires only common-sense and that the money spent on engineering is wasted; even in the Road Departments, many of the men take this view, but it is a relic of the old "hit or miss" style of town-road construction. There is no doubt that money judiciously spent in engineering is justified by the resultant saving in total cost; there is also no doubt that much of the money spent in so-called engineering is absolutely wasted. In order to handle satisfactorily the work already in sight, we must have a larger force of technically trained roadmen, who realize the importance of the problem as an ENGINEERING PROBLEM, and who understand that a good design depends on them and not on a mechanical use of Standards. As soon as such a force is developed we can do justice to the roads.

GENERAL

HIGHWAYS are improved to reduce the cost of hauling and to increase the safety and ease of light traffic. The parts of the design are more or less important in proportion to their necessity for the fulfilment of these purposes, and may be ranked as follows:

1. Selection of Roads
2. Grades and Alignment
3. Cross Sections
4. Drainage
5. Foundations
6. Top Courses
7. Minor Details

The Selection of Roads to improve is a matter of broad policy; it *becomes an engineering* question only when a number of road

serve the same district, in which case the considerations of grade and economy govern.

Grades, Alignment, and Section are the most permanent features of an improvement. The ruling grade largely controls the maximum load that can be hauled; section and grade combined determine the convenience of the road and the economy of earthwork, while alignment and section affect the safety and are also important factors in the appearance of the highway. For these reasons these three points can be ranked as equal and first in importance.

Drainage, Foundation Stone, and the Top Course keep the section intact and firm under heavy traffic. The bearing power of the subgrade and shoulders is increased by the surface and subsurface drainage; the concentrated wheel loads of heavily loaded vehicles are spread over a safe area of subgrade by the foundation stone; the top course provides a surface that will withstand the abrasive action of wheels and horse-shoes, that gives a good footing and offers slight rolling resistance. At the present time the problem of the top course is more troublesome than all the other points combined, and various new styles of construction are being tried to meet the demands of both automobile and horse traffic. There is so much discussion of this one feature that it is easy to give it too much weight, and there is a tendency to economize on the more permanent and important parts of the design in order to get a higher grade top course. In the writer's opinion this is a mistake. The different types of experimental top courses will be described in detail, but as yet no definite conclusions can be drawn.

Minor Details

Minor Details include guard-rail, danger signs, guide signs, and other points affecting the safety and general appearance of the road.

The steps of the design will be taken up in the order of their importance as indicated on page 1.

CHAPTER I

GRADES AND ALIGNMENT

Grades can be divided into Maximum, Minimum, and Intermediate.

Maximum or Ruling Grades

It is impossible to do justice to the question of ruling grades in the brief discussion called for by a book of this character, but the main points will be covered in the following order:

1. The relative importance of automobile and horse traffic in the selection of grades.
2. The difficulty of ascent and the ease and safety of descent.
3. The theoretical grades that fulfil certain traffic requirements, and the practical considerations that govern the selection.
4. The construction of ruling grades.

1. Under favorable conditions, gasoline and electric trucks can haul for about $0.08 to $0.10 per ton mile, traveling empty one way, while the cost of team hauling cannot be reduced much below $0.16 to $0.18. This looks like a big advantage for the trucks, but they are helpless on a poor foundation and their use for general purposes in the country is limited by bad side-roads and snow, and for produce hauling is confined to the short period of the year in which the crops are marketed. Near cities they are coming into use for milk routes, gardening produce, and the rural delivery of merchandise, but only on improved roads and only by concerns that are able to use them continuously enough to warrant the investment. Farmers must keep horses for their ordinary work and, having them, will continue to draw with teams. Mechanical trucking is bound to increase, but there seems to be no reason to believe that it will become more important than team hauling, and as the machines in use have sufficient power to take their full loads up any firm surfaced grade that has heretofore been considered suitable for horse traffic, it is evident that for heavy hauling, teams still govern the selection of grade.

In Europe, mechanical tractors drawing trains of farm wagons have been used successfully. This style of hauling will probably be adopted here for limited areas, but its development into general use is a matter of conjecture. The number of wagons drawn by one machine is limited to seven or eight by the difficulties at turns and the danger of obstructing the road, rather than by the present grades. Reduced grades would lessen the fuel consumption and increase the speed slightly, but would not materially increase the train load. It would seem that such a small saving for a class of traffic that is to be developed in the future would not warrant any reduction of grade below current practice.

Light automobiles are not handicapped as much by bad roads as the heavy trucks; on fair roads their ability to cover long distances quickly makes them adapted to many uses, but they are not now

and probably never will be, as effective as horses for general use under all conditions. The least powerful of these light machines have no difficulty on firm surfaced 8% to 10% grades, which eliminates them as a factor in determining the maximum rate. From the preceding statements of the present and probable future conditions of both light and heavy traffic it is reasonable to conclude that the horse and not the machine should govern the design of the Ruling Grade.

2. Various grades on country roads have been under observation for so many years that it is safer to be guided by present practice, which is the result of such observation, than to trust too much to a theoretical discussion. The adoption of the ruling grades given in Table 1 has depended partly on the ease of maintenance as well as the traffic considerations; the maximum grades on which different top courses can be safely used, either on account of foothold for horses or the maintenance of the surface, properly come under a discussion of such courses, and will be included in chapter V.

TABLE I

RULING GRADES IN FOREIGN COUNTRIES

	Mountainous Districts	Hilly Districts	Level Districts
Prussia	5 %	4 %	2½%
Hanover	4 %	3½%	2½%
Baden	8 %	6 %	5 %
Brunswick	5½%	4 %	3 %
Holyrod Road in England	6 %	3½%	—
Military Highway over the Alps	Italian side 4½%	Swiss side 6 %	
	National Roads	Departmental Roads	Subordinate Roads
France	3%	4%	6%

RULING GRADES IN THE UNITED STATES

State	Main Roads	Side Roads	Unusual Cases
New York	5%	7 & 8%	11%
Massachusetts	5%	7%	—
Connecticut	5%	–	—
New Jersey	5%	6–7%	9%
Michigan	6%	—	—
Missouri	5–6%	—	—
Washington	5%	5%	—
Illinois	6%	—	9%

European observers claim that on a stone road, 5% is the maximum grade that can be descended safely by a trotting team without the application of brakes, and that 12% is the maximum that can be descended safely with brakes. Safe descent with brakes need not be considered, as it would result in a grade far beyond ordinary practice; safe and easy descent without brakes very evidently plays a part in the selection of the ruling grade, but is more important for light teams with a small load, traveling at a comparatively rapid rate, than for heavy hauling teams which rarely trot.

The writer knows of no records of actual maximum loads that can be drawn up different grades by an ordinary team; it is probably better to discuss this point theoretically, as any experiments would be affected by too many variable local conditions to be worth much as a basis for comparison.

A summary of Prof. I. O. Baker's discussion of maximum team loads is given below, and through his courtesy we are enabled to include a collection of tables taken from his work "Roads and Pavements."

Various trials have determined that the normal tractive power of a horse traveling three miles per hour for ten hours a day is approximately one tenth of its weight; that when hauling up a steep grade it can exert one fourth of its weight for a short time; that for a continuous exertion of one fourth, the grade should not be over 1200 feet long, and if over that, resting places must be provided every 600 to 800 feet; that in starting and for a distance of 50 to 100 feet, one half of its weight can be used; and that the net tractive power exerted by a horse on a grade equals ($\frac{1}{4}$ its weight) — (the effort required to lift itself), or approximately $W/4 - W \times$ per cent of grade expressed in hundredths, i.e. $(W/4 - 0.04W)$ for a 4% grade.

Table 2 shows the effective tractive power of a team of 1200-pound horses on different grades.

TABLE 2

	Grade	Theoretical Tractive Effort	Tractive Effort in Pounds
	Level	$\frac{1}{10}$ W	240
	2½%	W/4 − PW	540
W = Weight of team, 2400 lbs.	4 %	W/4 − PW	504
	5 %	W/4 − PW	480
P = Per cent of grade in hundredths........	6 %	W/4 − PW	456
	7 %	W/4 − PW	432
	8 %	W/4 − PW	408
	9 %	W/4 − PW	384
	10 %	W/4 − PW	360

This *power is used in* overcoming axle friction, gravity resistance, *and rolling resistance.*

The axle friction is small, amounting to three or four pounds per ton for American farm wagons.

Grade resistance (gravity) equals (Load x per cent of grade expressed in hundredths) and expressed in pounds per ton of load equals (2000 x P).

The rolling resistance varies for different surfaces and for each surface depends on the diameter of wheel, width of tire, speed of travel, and the presence or absence of springs on the wagon. The best diameter of wheels, best width of tires, and the use of springs as they affect the ease of hauling for both farm and road use are problems for the wagon manufacturers.

Morin, a French engineer, concluded, from a series of careful experiments, that the harder the surface of the road the less effect the width of tire had on rolling resistance. We are dealing with comparatively hard surfacing only and with small differences in wheel diameters and can disregard these factors. As a matter of interest Tables 3, 4. and 5 are included to show the results of experiments on different soils and roads.

The question of wide tires is necessary to road engineers only as it affects the distribution of wheel loads over a safe area and will be taken up under Foundations.

TABLE 3.—EFFECT OF WIDTH OF TIRE UPON TRACTIVE POWER[1]
RESISTANCES IN POUNDS PER TON

Ref No.	Description of the Road Surface	Diameters of the Front & Rear Wheels respectively									
		3'-6" & 3'-10"		3'-6" & 3'-10"		3'-8" & 4'-6"		3'-6" & 3'-10"		3'-8" & 4'-6"	
		Width of Tires									
		1½"	4"	1½"	4"	1½"	4"	1½"	3"	1½"	3"
1	Sod							283	239	189	228
2	Earth road (hard)		108					252	252	114	114
3	" " (muddy)		243	268	304	236	254			265	228
4	Sand " (hard)	199	162	171	164	141	168				
5	" (deep)	371	351								
6	Gravel road (good)			98	117	83	80			66	76
7	Wood Block (round)	51	49	61	70	35	46		54	28	38

[1] Pamphlet by Studebaker Brothers Manufacturing Company, 1892.

TABLE 4. — EFFECT OF SIZE OF WHEELS ON TRACTIVE RESISTANCE[1] POUNDS PER TON

Ref. No.	Description of Road Surface	Mean Diameter of Front & Rear Wheels		
		50″	38″	26″
1	Macadam, slightly worn, fair condition	57	61	70
2	Gravel road, sand 1″ deep, loose stones	84	90	110
3	" " upgrade 2.2%, one-half inch wet sand, frozen below..........................	123	132	173
4	Earth road. Dry and hard	69	75	79
5	" " ½″ sticky mud, frozen below.....	101	119	139
6	Timothy & blue grass sod, dry grass cut	132	145	179
7	" " " " " wet & spongy......	173	203	281
8	Cornfield; flat culture across rows, dry	178	201	265
9	Plowed ground; not harrowed, dry & cloddy ..	252	303	374
10	Average Value of Tractive Power	130	148	186

[1] Experiments of Mr. T. I. Mairs at the Missouri Agricultural Experiment Station.

TABLE 5. — TRACTIVE RESISTANCE OF BROAD AND NARROW TIRES.[1] RESISTANCE IN POUNDS PER TON

Ref. No.	Description of Road Surface	Width of Tire 1½"	Width of Tire 6"	No. of Trials
1	Broken Stone, Road; hard, smooth, no dust, no loose stone	121	98	2
2	Gravel Road; hard and smooth; a few loose stones	182	134	2
3	" " " no ruts, large quantity of sand	239	157	1
4	" " new gravel, not compact, dry	330	260	1
5	" " wet, loose sand 1" to 2½" deep	246	254	2
6	Earth Roads. Loam, dry, loose dust 2" to 3" deep	90	106	2
7	" " " dry and hard, no dust, no ruts, nearly level	149	109	3
8	" " " stiff mud, drying on top, spongy below	497	307	1
9	" " " mud 2½" deep, firm below	251	325	1
10	" " Clay, sloppy mud, 3" to 4" deep, hard below	286	406	1
11	" " " dry on top but spongy below	472	422	2
12	" " " dry on top but spongy below	618	464	5
13	" " " stiff deep mud	825	551	1
14	Mowing Land. Timothy sod, dry, firm, and smooth	317	229	1
15	" " " " moist	421	305	1
16	" " " " soft and spongy	569	327	1
17	Pasture " Blue grass sod, dry, firm, and smooth	218	156	2
18	" " " " " soft	420	273	2
19	" " " " " soft	578	436	1
20	Stubble " Corn stubble, no weeds, dry enough to plow	631	418	2
21	" " " " some weeds, dry enough to plow	423	362	1
22	" " " " in Autumn, dry and firm	404	256	2
23	Plowed " Freshly plowed, not harrowed, surface rough	510	283	1
24	" " " " harrowed, smooth, compact	466	323	1

[1] Missouri Agricultural Experiment Station Bulletin No. 39.

Table 6 gives the average rolling resistance in pounds per ton of load on different pavements for the ordinary farm wagon driven at ordinary speeds.

TABLE 6 [1]

Kind of Pavement	Rolling Resistance in Lbs. per Ton of Load
Asphalt	30 to 70
Brick	15 to 40
Cobble Stones	50 to 100
Earth Roads	50 to 200
Gravel Roads	50 to 100
Macadam Roads	20 to 100
Plank	30 to 50
Stone Block	30 to 80
Wood Block	30 to 50

[1] Baker's "Roads and Pavements."

For a comparative estimate we will take a value of forty pounds per ton of load, including axle friction, on Bituminous Macadam, Waterbound Macadam, and Brick Pavement, and one hundred pounds per ton for earth roads in fair condition. The resistance to the effective tractive power of the team per ton of load is therefore 40 + (2000 x P) on the improved roads, and 100 + (2000 x P) for earth roads, and the maximum load that can be drawn on any grade equals

$$\left(\frac{\text{Effective tractive power of team for that grade}}{\text{Resistance per ton of load for that grade}}\right)$$

Using the tractive powers of the team shown in Table 2, the following table is constructed.

TABLE 7

Grade	Effective Tractive Effort	Improved Roads: Resistance in lbs. per Ton of Load	Improved Roads: Maximum Load in Tons	Earth Roads: Resistance	Earth Roads: Max. Load
Level	240 lbs.	40 lbs.	6.0 tons	100 lbs.	2.4 tons
2½%	540 "	90 "	6.0 "	150 "	3.6 "
4 %	504 "	120 "	4.2 "	180 "	2.8 "
5 %	480 "	140 "	3.4 "	200 "	2.4 "
6 %	456 "	160 "	3.0 "	220 "	2.1 "
7 %	432 "	180 "	2.4 "	240 "	1.8 "
8 %	408 "	200 "	2.0 "	260 "	1.6 "
9 %	384 "	220 "	1.7 "	280 "	1.4 "
10 %	360 "	240 "	1.5 "	300 "	1.2 "

NOTE.— This table is chiefly useful in comparing the effect of different grades on improved and unimproved roads, but in the writer's opinion the theoretical loads are nearly correct.

3. From Table 7 and the preceding discussion we can pick out the grades that theoretically fulfil certain traffic requirements.

I. On improved roads the same load that can be drawn up a 2½% grade by the maximum exertion of a team, can be hauled on a level with normal exertion. This makes a perfectly balanced design from the standpoint of team hauling. The theoretical load is six tons.

II. 5% is the maximum grade that fulfils the condition of safe descent at a trot without brakes; this requirement is more important for light than for heavy traffic. The theoretical load for this grade is 3.4 tons.

III. The same load that can be hauled up a 7% improved grade can be drawn on a level dirt road in fair condition; a 7% grade therefore does not reduce the load of a team which must travel over an earth road for part of the distance. The theoretical load is 2.4 tons.

As a matter of fact, the actual traffic conditions, the topography of the country, and the money available, govern the selection of the grade. The theoretical advantage of a 7% grade does not really amount to much, as where the improved road has a small ruling grade, the farmers often use snatch teams to draw to the road and single teams for the balance of the distance. The adoption of 7% by many of the States depends on the topography, as will be shown later.

The average farm wagon in New York State weighs about 1350 pounds, and 3500 pounds is a large net load for such a wagon; even with larger wagons and a snatch team it is not likely that more than four tons would be drawn over dirt roads to the improved road. There is no possibility of an average team load of six tons, which means that a 2½% ruling grade need not be considered except in flat country where it can be built cheaply. A 5% grade has been found from experience to be satisfactory for most localities, as 3½ to 4 tons can be hauled, teams can descend it easily, and the cost of construction is usually not too great.

In the improvement of any highway or system of highways, the amount of money that the community is willing to provide is often insufficient to build a road that the conditions demand. This limits the engineer to the best design he can make for the amount available. In such a case the grade should be consistent even if it cannot be reduced to a rate that would meet the traffic requirements, and should be designed primarily for heavy hauling. As the advantages of these roads are demonstrated, there is less difficulty in getting sufficient money for a good design.

Take for example a road between two shipping points. It is first necessary to determine the portion tributary to each shipping center, and then the natural grade of all the hills on each portion, in order to decide what consistent ruling grade can be adopted without excessive cost.[1] There is no object in reducing a hill from 7% to 5% at a large expenditure if nearer the terminal there is a grade that cannot be reduced below 7%. It should be borne in mind, however, that the nearer you approach the center, the more traffic the road will have, and if the hills are naturally flatter the ruling grade should be reduced. The direction of heavy traffic on each hill should be determined and

[1] *For an example, see page 124, chapter VIII.*

considered. In the writer's opinion there are few cases where grades less than 5% are required, and in hilly country 7% is satisfactory and a great improvement over previous conditions.

Grades as high as 11% have been constructed in New York and grades as high as 9% in New Jersey and Illinois, but the general opinion of the Departments under which these grades were built is that they would not again use such a high rate except in villages where any material change in street elevation would damage valuable properties. Outside of corporations it is bad practice to use grades greater than 7%, for if any road is of sufficient importance to warrant an improvement of the class discussed in this book, it is certainly of sufficient importance to warrant a reduction in grade to a reasonable rate.

4. CONSTRUCTION OF MAXIMUM GRADES

Natural grades are reduced to the required rate by cut and fill, by new locations around hills, or by new locations giving additional length for the same rise. The cheapest method is usually adopted, but sometimes where cut and fill would be the most economical in the first cost, the danger of drifting snow in cuts or the damage to abutting property from deep cuts or high fills results in the selection of the more expensive construction. A large reduction of grade on a long hill necessarily requires a new location.

MINIMUM GRADES

Most road books claim that level grades should not be used because of the liability of water standing in ruts and that a certain minimum grade should be adopted that would insure their longitudinal drainage. Baker states in his "Roads and Pavements" that for macadam roads, English engineers use a minimum grade of 1.5%, French engineers 0.8%, and that American practice favors 0.5%. Let us see what this means:

for a 1.5% grade the fall would be 1/5 inch per foot
" " 0.8% " " " " " 1/10 " " "
" " 0.5% " " " " " 1/16 " " "

The flattest crown that is ordinarily used even on bituminous macadam is ½" per foot or 2½ times as much as the greatest longitudinal fall in the above list.[1] For long ruts a longitudinal grade is of course effective, but the patrol system of maintenance is supposed to prevent their formation and for short small depressions the crown slope must furnish the drainage. The writer believes that there should be no hesitation in using a level grade; on such stretches the crown can be increased slightly to insure transverse drainage and the ditches given a minimum longitudinal fall of 0.2′ to 0.5′ per 100′, depending on the soil.

INTERMEDIATE GRADES

The selection of the intermediate grades affords the greatest chance for economy *on earth work*. A grade so established that the cut in

[1] See footnote, page 18.

every cross-section would just make the fill at that point, would result in the least possible excavation. This condition is never realized, but the nearer it is approximated, the nearer we get to the most economical grading design. (See chapter on Office Practice, page 185.)

It may be noted at this point that economy of grading should never govern the profile or cross-section where there is any good reason of convenience, safety, or appearance for placing the road at a certain elevation or giving it a certain shape.

In determining the profile the controlling features should first be noted; these are high-water level of streams, elevations of existing bridges, railroad crossings, all points where deep cuts or high fills would damage the approaches to valuable property; connections with other highways, portions of the road that have been previously macadamized, and in villages the elevation that will give a convenient section and a finished appearance. The adopted grade must satisfy these conditions. However, on the greater part of an ordinary road, the grade can be placed at any desired elevation, and it is on these stretches that the saving in earthwork is effected. To get an economical design, a rolling grade can be used if necessary; long straight grades are not required, a mistake easily made by engineers trained in railroad work. Short grades are not objectionable, and a reverse vertical curve rides easily if well built. It appears that there is too much tendency to cut the top of every knoll and fill each hollow, for it seems a waste of money to reduce a 4% to a 3.5% or a 3.5% to a 3% grade where the ruling grade is 5%. There should be no hesitation in spending all the money that can be obtained to reduce the ruling grade to a reasonable rate, but it is good policy to economize on all grades less than the maximum.

In conclusion, it should be stated that probably the most common error in the laying of a profile consists in making the excavation and embankment balance with short hauls, *regardless* of more important considerations, and in this connection it cannot be stated too strongly that the grade must satisfy the controlling points; that any resulting excess of material must be overhauled or wasted and any shortage borrowed; that the economies must be effected on the unimportant stretches of road, and that by the use of short and rolling grades the excavation can be reduced and a good profile obtained.

Table 8 gives the excavation per mile on State roads in different localities and indicates the variation in amount that is required to get a first-class improvement.

TABLE 8

PART 1. — COMPILED FROM THE 1908 AND 1909 REPORTS OF THE NEW JERSEY HIGHWAY COMMISSION.

Name of Road	Length in Miles	Maximum Original Grade	Max. Improved Grade	Excavation in cu. yds. per Mile
May's Landing	14.0	7.0%	3.2%	2,220
Rivervale	5.0	8.5%	5.0%	4,680
Westwood	1.2	5.2%	4.5%	2,500
Franklin Turnpike	1.6	8.0%	2.8%	8,200
Summit	1.9	13.0%	6.5%	5,200
Lamberton	3.9	2.8%	2.8%	540
Westfield	3.1	4.5%	2.9%	6,500
Blue Anchor	2.3	2.5%	2.0%	3,200
Malaga	5.7	4.2%	2.0%	1,700
Whitehouse	6.5	12.5%	5.0%	4,100
English Creek	6.7	6.0%	3.0%	2,000
Paterson Plank Road	2.3	Level	Level	(Emb.) 50,000
Yesler Way	2.7	12.0%	6.5%	5,700
Camden	2.4	6.7%	4.0%	5,200
Evesham	2.4	6.4%	3.7%	3,500
Schellenger's Landing	2.1	3.4%	1.1%	5,000
Goshen	2.6	3.4%	1.4%	4,500
Tuckahoe	4.3	4.1%	1.6%	8,100
Hopewell	2.0	7.6%	5.0%	3,800

TABLE 8

PART 2. — COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans for 1911

Name of Road	Character of Country	Maximum Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
Pittsford — North Henrietta	Rolling	5.0%	24′	2500
Indian Falls — Corfu	Flat	1.6%	24′	2800
Pembroke — East Pembroke	Hilly	5.0%	42′	3600
Livonia — Ontario County Line	Hilly	8.0%	32′	5500
Livonia — Lakeville	Hilly	8.0%	32′	4500
Avon — Lima	Hilly	8.0%	32′	3300
Sea Breeze — Nine Mile Point	Hilly	8.0%	26′	6600
Bliss — Smith's Corners	Rolling	5.5%	26′	3400
Wales Center — Wales	Hilly	8.0%	28′	5700
Scottsville — Mumford	Rolling	5.0%	32′	3400
Ridge — Rochester — Sea Breeze	50% Flat 50% Hilly	1.5% 5.0%	32′ & 44′	3350
Medina — Alabama	Rolling	5.0%	28′ 32′	2800
Pavilion — Batavia	Hilly	10.0%	22′–30′	2950
Parma Corners — Spencerport — North Chili	Flat	6.0%	32′	2520

TABLE 8. *Continued*

COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans for 1910

Name of Road	Character of Country	Maximum Improved Grade	Width of Section between Ditches	Exc. in Cu. Yds. per mi
Lake Part 2 & Sweden 4th Sect	Flat	3.8%	32′	2560
Warsaw — Pavilion	"	5.0%	28′-32′	3000
East Henrietta — Rochester	Rolling	3.8%	32′	2300
Olean — Hinsdale	Flat	2.6%	28′ 32′	4000
Leroy — Caledonia (1 5 miles)	Rolling	5.0%	32′-40′	1950
Shawnee Cambria	60% Flat 40% Hilly	2 2% 7.0%	28′ 32′	3150
Roberts Road	Rolling	3 1%	32′	3230
Sanborn — Pekin	Flat	2 4% One hill 5.0%	32′	2800
Oak Orchard, Part 2	Rolling	4.4%	30′ 32′	2300
Levant — Poland Center	Hilly	5.0%	28′-32′	4000
Dansville — Mt. Morris. II	"	4.1%	24′	6200
Castile Center Perry Center	Flat	3.6%	30′	2870
Lake Shore — Lackawanna City	"	0.7%	28′ 32′	2120
Eighteen Mile Creek	Hilly	7.0%	28′-32′	6100
Albion Street — Holley	Rolling	3.7%	32′	3440
Pembroke — East Pembroke	"	5.0%	32′	3800

TABLE 8. *Continued*

COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans for 1908 and 1909 (Selected Roads)

Name of Road	Character of Country	Max. Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
Hamburg — Springville Sect. I	Rolling	6.0%	30'	1920
" " " II	Hilly	7.0%	30'	3100
Collins — Mortons Corners . . .	"	7.0%	32'	2250
Clarence Center . .	Flat	2.5%	28'	2200
Orchard Park — Griffin's Mills . .	Hilly	8.0%	28'	2000
County Line	Flat	5.0%	28'–32'	2100
Geneseo — Avon . . .	Hilly	5.3%	32'	2200
Geneseo — Mt. Morris . .	"	6.0%	32'	3460
Alden — Town Line . .	Flat	6.0%	22'–28'	1960
Pittsford — Mendon .	Hilly	6.0%	32'	3000
Pittsford – Despatch .	"	5.0%	24'	3600
Clover Street Section I	"	8.0%	28'	2550
" " " II	Rolling	4.5%	32'	3000
Rich's Dugway . . .	Hilly	7.3%	20'–28'	5000
Left Fork — German Church . .	Rolling	6.2%	28'	2000
Goodrich Road	60% Flat 40% Rolling	5.0% 6.0%	26'–32'	3100
Hamburg — North Collins .	Hilly	9.0%	22'–32'	4200
Lawton — Gowanda . .	"	7.5%	32'	5300
Chili	Rolling	5.0%	28'	2800
Brooks Avenue	Flat	4.6%	24'–30'	2240
Lyell Avenue . . .	"	2.2%	26'–30'	2400
Barnard's Crossing	"	4.4%	22'	2174

TABLE 8. *Continued*

COMPILED FROM THE RECORDS OF THE NEW YORK STATE HIGHWAY COMMISSION.

Plans from 1898 to 1907. (Selected Roads)

Name of Road	Character of Country	Max. Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
East Avenue . .	Rolling	5.0%	22'	8160
Pittsford . .	"	5.0%	22'	5840
Fairport	"	5.5%	20'–22'	6580
Ridge Road	"	3.3%	26'	2150
Buffalo Road	Flat	2.0%	22'–25'	1700
White's Corners Plank Road	"	3.5%	22'	4600
Orchard Park	"	3.0%	20'	4200
Transit. Sections I & II . .	"	4.6%	22'	2100
Hudson Avenue Road	Rolling	3.1%	22'	7100
West Henrietta . .	Flat	5.5%	22'	3400
Scottsville, Section I	"	4.0%	22'	2000
" " II	Rolling	5.0%	22'	2100
Monroe Avenue	Flat	4.5%	22'–24'	1850

An examination of the 1909 report of the New York State Highway Commission shows that the largest excavation per mile on roads built by the State from 1898 to 1908 was as follows:

Delaware Turnpike Road ... 1.04 miles ... 16800 c.y. per mile
" " " ... 6.5 " ... 6800 " " "
North Creek-County Line 4.12 " ... 10300 " " "
Highland Lake-Tompkins Cove 5.88 " ... 10100 " " "

and the least excavation as follows:

Main Street, Section II 986 " " "
Babylon-Bay Shore 735 " " "

TABLE 8

PART 3. — COMPILED FROM THE REPORTS OF THE MASSACHUSETTS STATE HIGHWAY COMMISSION. 1896

Name of Road	Length in Miles	Maximum Improved Grade	Width of Section between Ditches	Exc. in cu. yds. per mi.
Andover	0.6	4.9 %	24	6000
Brewster	1.0	3.36%	21′	2607
Dalton	1.5	6.0 %	30′	1920
Gloucester	1.6	5.0 %	21′	3200
Granby	0.63	2.7 %	21′	5300
Great Barrington	1.0	2.6 %	21′–24′	2300
Hadley	1.49	4.0 %	21′	8930
Munson	0.93	2.95%	21′	3000
Norfolk	1.2	5.3 %	21′	3350
North Hampton	0.56	1.25%	26′	4300
Pittsfield	1.0	4.25%	21′	4700
Tisbury	1.93	4.40%	21′	7540
Westport	3.0	1.7 %	24′	1500
Wrentham	1.62	4.0 %	21′	3700
Walpole	1.61	6.0 %	21′	5600
Duxbury	1.05	3.8 %	21′	3800
Fairhaven	1.45	4.0 %	21′	1200
Fitchburg	0.97	6.0 %	21′	4500
Goshen[1]	1.91	5.0 %	21′	9700
Marion	1.48	5.0 %	21′	1500
Mattapoisett	1.16	4.25%	21′	1810
Lee	1.5	5.16%	—	3500
Leicester	2.0	5.0 %	—	3800

This table is compiled to show the amounts of excavation that the Highway Departments of Massachusetts, New York, and New Jersey have been willing to use in getting various maximum grades. It can be readily seen that it is impossible to generalize as to how much excavation will be required. In the chapter on "Sections" some examples will be given of roads for which two designs were made, using different widths of section and different kinds of profile, to show the saving that can be effected by a careful selection of the section and *the use of a* rolling grade.

[1] *Original maximum grade 12%* — new location used; as difficult a road as there *is in the State to obtain a 5%* grade.

ALIGNMENT

Sharp curves on steep grades or at the foot of such grades are not
s ... practice calls for a minimum radius of 300 to 400 feet for
... Right angle turns even on level stretches are incon-
...en dangerous. New York State has adopted a radius
... minimum, wherever possible, acquiring new right-of-
...ssary, and it is very evident that the increased comfort
... traveling public.

...ively straight stretches the position of the center-line
...ated to keep on the old roadbed as much as possible and
...leasing appearance; this is done to utilize the hard founda-
...e present traveled way for the subgrade of the proposed.

Sight Distances. — In designing a side hill road, in rough country, the alignment and width of shoulder often depends upon what we may call "a safe sight distance"; this means that the driver of a machine, traveling at ordinary touring speed of 20 to 30 miles per hour, must be able to see far enough ahead to turn out and pass an approaching car without the application of brakes. In attempting to reach a conclusion as to what is a "safe sight distance" we have written to automobile clubs throughout the country and find that, in the main, they agree on from 200 to 300 feet for speeds of 20 to 25 miles per hour.

Mr. George C. Diehl, Chairman of the Good Roads Board, A.A.A. and County Engineer of Erie County, N.Y., gave us the following information for emergency stops and passing without slowing up:

"The tests that we have conducted show that a car going at the rate of 20 miles per hour can be stopped at 40′ and one going at 40 miles per hour can be stopped at 140 feet with the emergency brake. For passing a rig going in an opposite direction this distance would not be necessary."

Mr. Diehl's figures are considerably less than the distances given in the other answers. A minimum sight distance of 250 to 300 feet is the practice of Division No. 5, New York State Department of Highways.

In the chapter on Office Practice, page 181, tables are given showing the "Sight Distance" for different curves in "cut."

Railway Grade Crossing Elimination

Grade crossings are being eliminated as rapidly as possible, as they are a source of great danger. The overhead clearance and width of roadway in subways are given in chapter IX.

CHAPTER II

SECTIONS

SECTIONS may be considered from the standpoints of safety, convenience, and economy.

For safety, a rig should be able to travel on any part of the road from ditch to ditch without overturning; for convenience, the width of section ordinarily used must have enough pitch to drain the surface water into the ditches but not enough to give an uncomfortable tilt to a vehicle; for economy, the section must be flexible in order to conform to local conditions.

The first questions are naturally: What is a safe slope? What is a comfortable driving slope? What pitch is required to drain different surfaces? What is the commonly used width, and what the maximum width of the traveled way?

All of these points except the last two have been pretty well determined, and, while some engineers disagree with current practice, the writer believes from his experience and a study of the various State sections that the following premises can be safely adopted:

That 3" to 1' or 1 on 4 is the maximum safe slope.

That 1" to 1' is the maximum agreeable driving slope.

That 1" to 1' is the minimum slope at which an earth shoulder will shed water, without too much maintenance.

That ⅝" to 1' is a satisfactory crown for a waterbound macadam road in order to maintain it satisfactorily, allowing for the flattening that occurs under traffic.

That ½" to 1' is a satisfactory crown on waterbound roads having tar or asphalt flush coats or on bituminous macadam or mineral bitumen.[1]

That ¼" or ⅜" to 1' is a satisfactory crown for brick pavement on country roads.

The width of roadway carrying the greater portion of the travel and the maximum width used when rigs turn out to pass are not so well established; these two points determine the most economical width of hard roadbed and the minimum convenient driving width, no part of which should have a transverse slope of more than 1" to 1'.

Probably the best data can be obtained from the reports of the Massachusetts Highway Commission, which resulted from a careful study of these widths on 160 improved roads during the years 1896, 1897, 1898, 1899, and 1900. Table 9 gives the results on a few roads showing the form used and the variation from year to year; the footnote for Table 9 gives a summary of the observations on all the roads for the years 1896 to 1899 inclusive: this brief was prepared by

[1] *New York State has* adopted for their 1912 work a crown of ½" per foot for water-*bound roads and* ¼" *per foot* for bituminous macadams; this is extremely flat, allow-*ing for the effect of traffic* (see Table 20, page 72).

. Y. McClintock, County Engineer, Monroe County, N.Y., and ;ives a better idea of the conditions than would be conveyed by rinting the original table in full.

TABLE 9. SHOWING WIDTHS OF TRAVELED WAY

Town or City	County	Width of Macadam	Maximum Width of Traveled Way				Width of Commonly Traveled Way			
			1896	1897	1898	1899	1896	1897	[illegible]	1899
Athol	Worcester .	17'	16'	16'	20'	18'	10'–12'	12'	14'	14'
Barre . . .	Worcester .	15'	—	13'	14'	14'	—	9'	7'	8'
Bedford	Middlesex .	15'	—	12'	15'	15'	—	8'	10'	9'
Chicopee . .	Hampden .	20'	—	20'	20'	20'	—	12'	12'	13'
Dalton .	Berkshire .	15'	20'	20'	21'	16'–21'	20'	16'	18'	12'–18'
Fitchburg (W.)	Worcester .	15'	15'	14'	18'	18'	10'	10'	15'	14'
Huntington .	Hampshire	15'	9'	12'	11'	12'	7'	8'	9'	8'
Lincoln	Middlesex .	15'	15'	15'	15'	15'	10'	9'	10'	10'
Marshfield	Plymouth	15'	14'	12'	11'	12'	8'	9'	7'	7'
North Adams	Berkshire	15'	10'–12'	13'	14'	15'–20'	8'–10'	9'	10'	12'
Orange . .	Franklin	17'	16'	16'	20'	20'	10'–12'	12'	15'	15'
Taunton	Bristol . .	15'	20'	20'	15'	18'	10' 15'	10'	8'	7'–12'

Width of traveled way on 160 roads in Massachusetts, measured uring the years 1896, 1897, 1898, and 1899, and printed in the report he Massachusetts Highway Commission for 1900.

The width of stone on these roads is given as 15' wide on 130, 12' ride on 3, and 10' wide on 2. It should be remembered that the tone is put on very much thicker in the middle than at the edges.

The maximum width of traveled way as measured was as follows:

9 ft. wide on	2 roads		18 ft. wide on	23 roads	
10 " " "	6 "		19 " " "	1 "	
11 " " "	2 "		20 " " "	10 "	
12 " " "	28 "		21 " " "	10 "	
13 " " "	8 "		22 " " "	1 "	
14 " " "	23 "		24 " " "	2 "	
15 " " "	30 "		25 " " "	4 "	
16 " " "	8 "		26 " " "	1 "	
17 " " "	1 "		33 " " "	1 "	

The width of commonly traveled way as measured was as follows:

7 ft. wide on	12 roads	14 ft. wide on	8 roads
8 " " "	17 "	15 " " "	13 "
9 " " "	25 "	16 " " "	2 "
10 " " "	32 "	18 " " "	4 "
11 " " "	10 "	20 " " "	2 "
12 " " "	30 "	22 " " "	1 "
13 " " "	3 "	25 " " "	1 "

The author has measured a number of the New York State improved roads and found that the width of heavy travel checked the Massachusetts results but that the maximum widths were more, averaging from 18 to 21 ft.; this probably can be explained by the

increase in automobile traffic since 1900, which, because of its highe speed, requires more room in passing.

Briefly stated, the widths subjected to hard wear on unimportan roads ranged from 8′ to 10′; on well traveled roads 10′ to 14′, and ir unusual cases 14′ to 16′. The maximum widths used varied fron 12′ to 14′ on the side roads, to 17′ and 18′ on the main thoroughfares and as mentioned above have increased to 18–21′ in the last fev years. From this data, it seems that the best practice at presen requires a driving width for "turn out" traffic of about 22′, with a variable width of strong metaling determined by the traffic require-ments and ranging from 10′ to 20′.

We have now practically developed a standard for the 22′ of drivin width; the metaling that is to carry the heavy traffic has a specifie crown for each variety and from the edge of the metaling to th limits of the 22′, the earth shoulder must have a slope of 1″ to 1′ o possibly ¾″ to 1′.

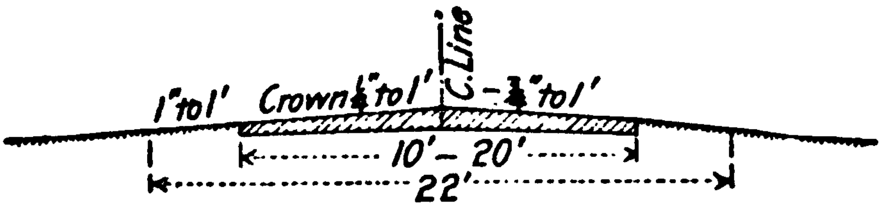


Fig. 1

The flexibility of the section depends on the portion outside o this 22′. The function of the extra width is to keep the longitudina drainage of surface water beyond the portion used for driving. T do this we are limited to a minimum slope of 1″ to 1′ to insure trans-verse drainage and a maximum of 3″ to 1′ on the score of safety. I is by the good judgment of the designer in using various slopes be-tween these limits and various widths and depths of ditches, combine with the possibilities of different grades, that the economies in earth-work are effected and at the same time the design is made appropriat to the local conditions.

Two examples are given to illustrate this point.

1. INDIAN FALLS—CORFU ROAD IN NEW YORK STATE

Original Design	Revised Design

Length 1.85 Miles.

NO CHANGE IN PROFILE

No Change in Ratio of Cut to Fill

Width of Macadam 14′	Width of Macadam 14′
" " Section 30′	" " Section 24′
Depth of Ditch 18″	Depth of Ditch 14″
Original estimated excavation 7500 Cu. Yds.	Revised estimated excavation 5200 Cu. Yds

This change is section alone resulted in a saving of 2300 cu. yds *excavation or at the* rate of 1240 cu. yds. per mile, or in money abou *$600.00 per mile.*

2. PITTSFORD — NORTH HENRIETTA ROAD IN NEW YORK STATE

Length 2.67 Miles

Original Design	Revised Design
Width of Section 30′	Width of Section 24′
Depth of Ditch 18″	Depth of Ditch 12″–14″
Ratio of cut to fill 1.35%	Ratio of cut to fill 1.25%
Maximum Grade 5.0%	Maximum Grade 5.0%
Profile: — Designed with straight instead of rolling grades and tangents of 100′ between vertical curves.	Profile: — Rolling grades and reverse vertical curves used.
Original estimated excavation 11,450 Cu. Yds.	Revised estimated excavation 6,620 Cu. Yds.

A saving of 4,820 cu. yds; 1,800 cu. yds. per mile, or, in money, approximately $900.00 per mile.

The revised design on this road is a good example of what can be saved by the use of a section that fits the conditions, a rolling grade, and a ratio of cut to fill that we have found from experience to be sufficient.

The author's experience has indicated that an open ditch does not have much effect on ground water; that its part in the design is to drain the surface water, thus preventing seepage into the road-bed with a resulting softening of the surface; and consequently, whenever ground water is encountered under drains should be used. Deep ditches are not only useless but dangerous, and the best practice calls for the least depth that will handle the surface water. The following section is, therefore, suitable where there is no probability of much surface water; it is the writer's idea of the minimum width section that will be satisfactory, and where it can be adopted will give the most economical grading design for light cuts and fills.

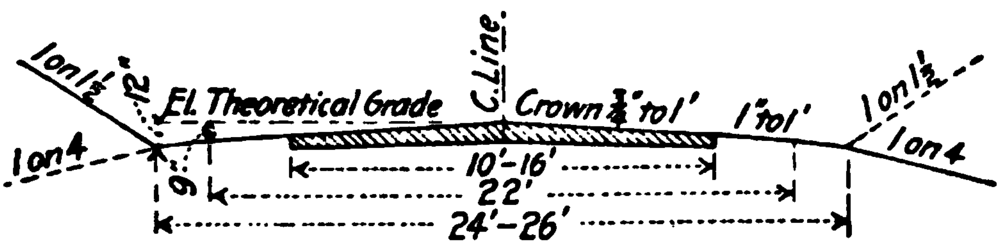
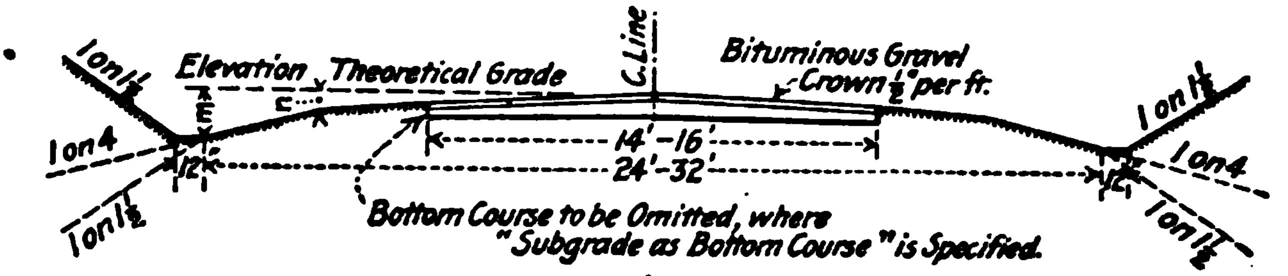
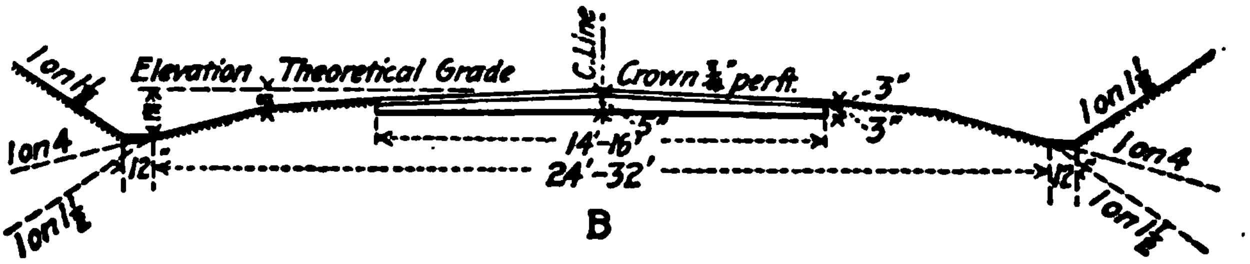


FIG. 2

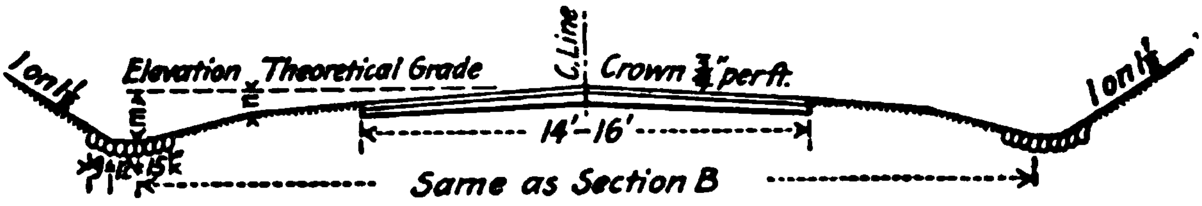
Plate 1 — New York State 1910 Standards



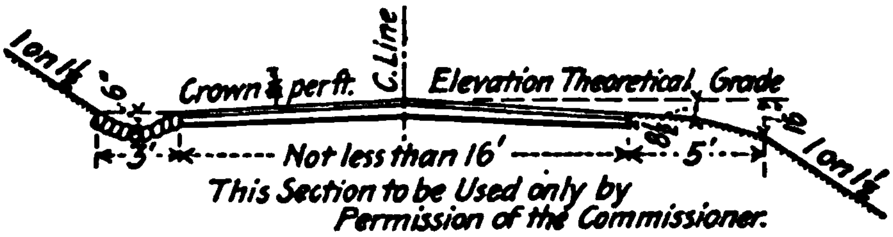
A



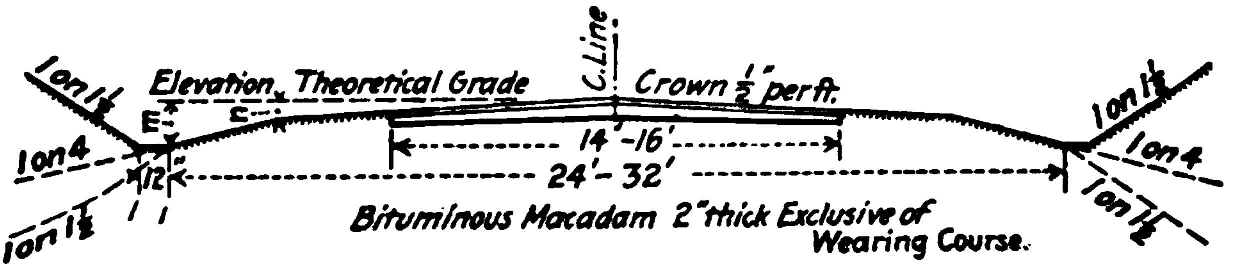
B



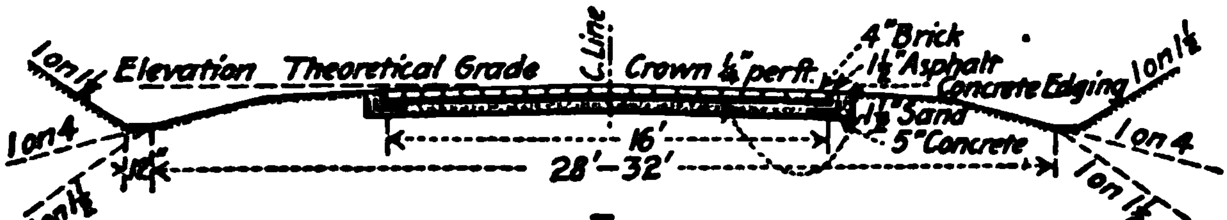
C



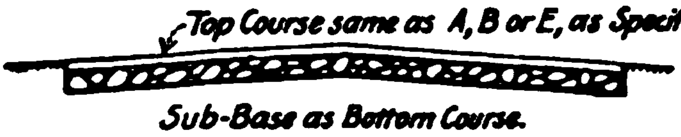
D



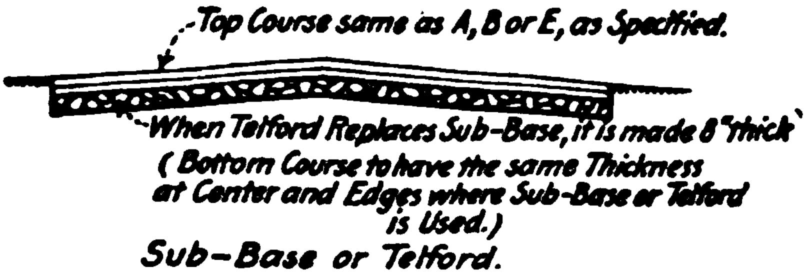
E


1 on 1½
Elevation
Theoretical Grade
℄ Line
Crown ¼" per ft.
4" Brick
1½" Asphalt
Concrete Edging
1 on 1½
1½" Sand
5" Concrete
1 on 4
16'
1 on 4
28'–32'
1 on 1½
1 on 1½

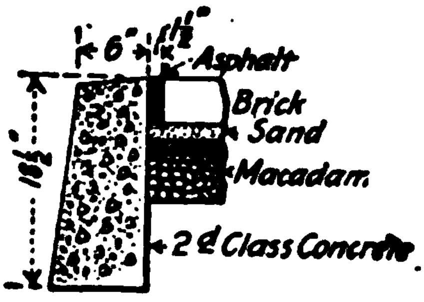
F

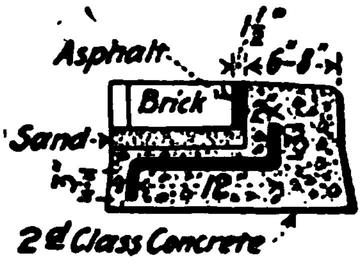

Top Course same as A, B or E, as Specified.
Sub-Base as Bottom Course.

G


Top Course same as A, B or E, as Specified.
When Telford Replaces Sub-Base, it is made 8" thick
(Bottom Course to have the same Thickness
at Center and Edges where Sub-Base or Telford
is Used.)
Sub-Base or Telford.

H


6"
1½"
Asphalt
Brick
Sand
Macadam
18"
2d Class Concrete


1½"
Asphalt
6"–8"
Brick
Sand
12"
2d Class Concrete

Dimensions for Typical Sections

Typical Section "A"

Crown of Gravel ½ inch to 1 foot

Diff. in Elev. between Center of Road and Center of Shoulder

Shoulder	Width of Gravel 14 feet	Width of Gravel 16 feet
5 feet	n = 6″	n = 6½″
6 feet	n = 6½″	n = 7″
7 feet	n = 7″	n = 7½″
8 feet	n = 7½″	n = 8″

Diff. in Elev. between Center of Road and Center of Ditch

Shoulder	Width of Gravel 14 feet	Width of Gravel 16 feet
5 feet	m = 13½″	m = 14″
6 feet	m = 15½″	m = 16″
7 feet	m = 17½″	m = 18″
8 feet	m = 19½″	m = 20″

Typical Section "B"

Crown of Macadam ½ inch to 1 foot

Diff. in Elev. between Center of Road and Center of Shoulder

Shoulder	Width of Macadam 14 feet	Width of Macadam 16 feet
5 feet	n = 7¾″	n = 8½″
6 feet	n = 8¼″	n = 9″
7 feet	n = 8¾″	n = 9½″
8 feet	n = 9¼″	n = 10″

Diff. in Elev. between Center of Road and Center of Ditch

Shoulder	Width of Macadam 14 feet	Width of Macadam 16 feet
5 feet	m = 15½″	m = 16″
6 feet	m = 17½″	m = 18″
7 feet	m = 19½″	m = 20″
8 feet	m = 21½″	m = 22″

Typical Section "E"

Crown of Macadam ½ inch to 1 foot

Diff. in Elev. between Center of Road and Center of Shoulder

Shoulder	Width of Macadam 14 feet	Width of Macadam 16 feet
5 feet	n = 5¼″	——
6 feet	n = 5¾″	n = 6¼″
7 feet	n = 6¼″	n = 6¾″
8 feet	n = 6¾″	n = 7″

Diff. in Elev. between Center of Road and Center of Ditch

Shoulder	Width of Macadam 14 feet	Width of Macadam 16 feet
5 feet	m = 12¾″	——
6 feet	m = 14¾″	m = 15¼″
7 feet	m = 16¾″	m = 17¼″
8 feet	m = 18¾″	m = 19″

Typical Section "F"

Crown of Brick ¼ inch to 1 foot

Diff. in Elev. between Center of Road and Center of Shoulder

Shoulder	Width of Brick 16 feet
5 feet	–
6 feet	n = 4¼″
7 feet	n = 4¾″
8 feet	n = 5″

Diff. in Elev. between Center of Road and Center of Ditch

Shoulder	Width of Brick 16 feet
5 feet	——
6 feet	m = 13¼″
7 feet	m = 15¼″
8 feet	m = 17″

Note: Differences in elevation given in tables are measured from the theoretical grade.

PLATE 2

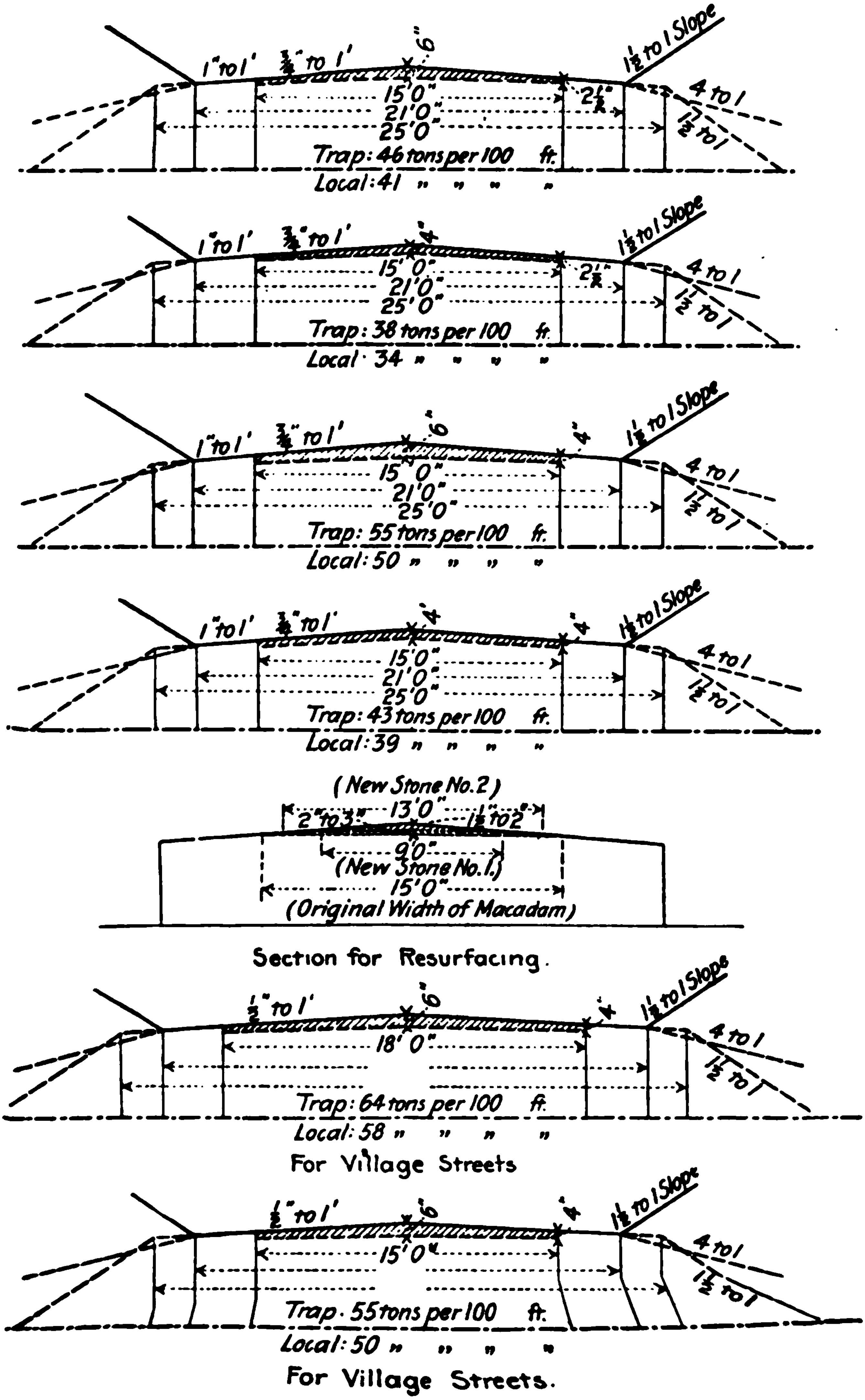
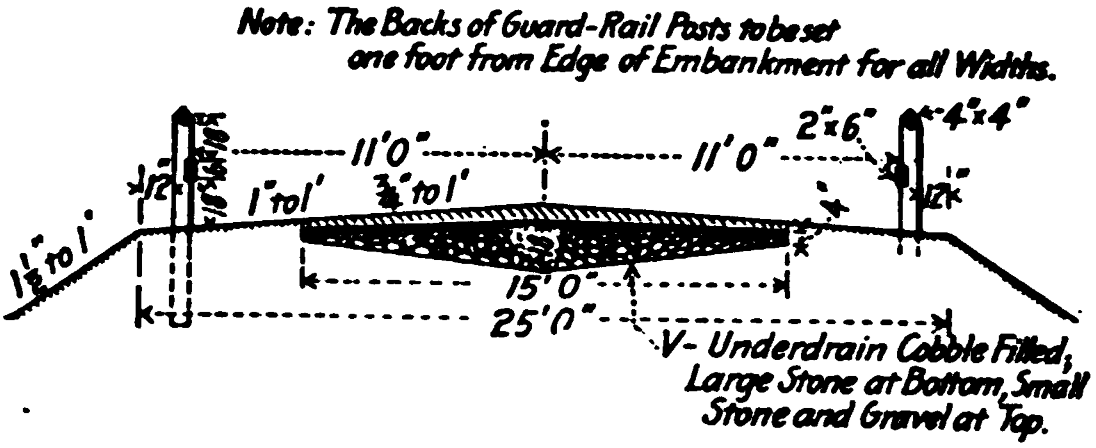
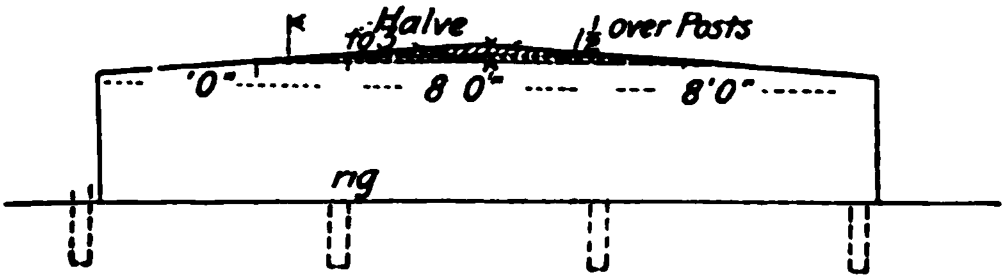
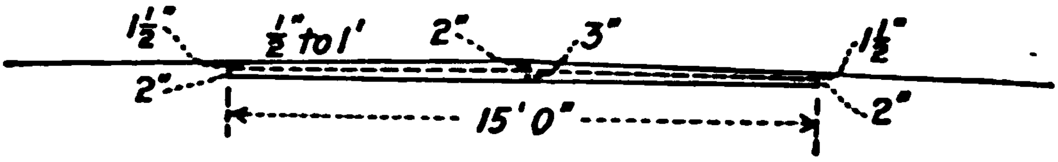

1" to 1'
¾" to 1'
6"
1½ to 1 Slope
15' 0"
21' 0"
25' 0"
2½"
4 to 1
1½ to 1
Trap: 46 tons per 100 ft.
Local: 41 " " " "
1" to 1'
¾" to 1'
4"
1½ to 1 Slope
15' 0"
21' 0"
25' 0"
2½"
4 to 1
1½ to 1
Trap: 38 tons per 100 ft.
Local: 34 " " " "
1" to 1'
¾" to 1'
6"
4"
1½ to 1 Slope
15' 0"
21' 0"
25' 0"
4 to 1
1½ to 1
Trap: 55 tons per 100 ft.
Local: 50 " " " "
1" to 1'
¾" to 1'
4"
4"
1½ to 1 Slope
15' 0"
21' 0"
25' 0"
4 to 1
1½ to 1
Trap: 43 tons per 100 ft.
Local: 39 " " " "
(New Stone No. 2)
13' 0"
2" to 3"
1½" to 2"
9' 0"
(New Stone No. 1.)
15' 0"
(Original Width of Macadam)
Section for Resurfacing.
½" to 1'
6"
4"
1½ to 1 Slope
18' 0"
4 to 1
1½ to 1
Trap: 64 tons per 100 ft.
Local: 58 " " " "
For Village Streets
½" to 1'
6"
4"
1½ to 1 Slope
15' 0"
4 to 1
1½ to 1
Trap. 55 tons per 100 ft.
Local: 50 " " " "
For Village Streets.

PLATE 2 — *continued*







CONDITION No. 1. — See note below.

Trap Rock — Lower course, No. 1 stone, 24 tons; screenings for binder, 4 tons. Upper couıse, No. 2 stone, 16 tons.

Local Stone — Lower course, No. 1 stone, 22 tons; screenings for binder, 4 tons. Upper course, No. 2 stone, 14 tons.

Total tonnage per 100′: Trap, 44; Local, 40.

CONDITION No. 2 — See note below.

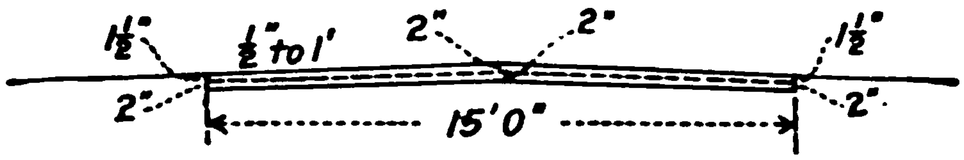
Trap Rock — Lower course, No. 1 stone, 24 tons. Upper course, No. 2 stone, 16 tons; screenings for binder, 7 tons.

Local Stone — Lower course, No. 1 stone, 22 tons. Upper course, No. 2 stone, 14 tons; screenings for binder, 7 tons.

Total tonnage per 100′: Trap, 47; Local, 43.

NOTE. — For both penetration methods — grouting or the modified Gladwell method — there should be two applications of asphaltic oil, each ¾ gal. per sq. yd. There may be also a third application of ½ gal. per sq. yd. for a surface finish. For surface treatment there should be one application of ½ gal. of oil per sq. yd. or two applications of ¼ gal. each per sq. yd. on the finished surface of the roadway.

PLATE 2 — *continued*



CONDITION No. 1.

Trap Rock — Lower course, No. 1 stone, 19 tons; screenings for *binder, 3 tons.* Upper course, No. 2 stone, 17 tons.

Local stone — Lower course, No. 1 stone, 17 tons; screenings for binder, 3 tons. Upper course, No. 2 stone, 15 tons.

Total tonnage per 100′: Trap, 39; Local, 35.

CONDITION No. 2.

Trap Rock — Lower course, No. 1 stone, 19 tons. Upper course, No. 2 stone, 17 tons; screenings for binder, 6 tons.

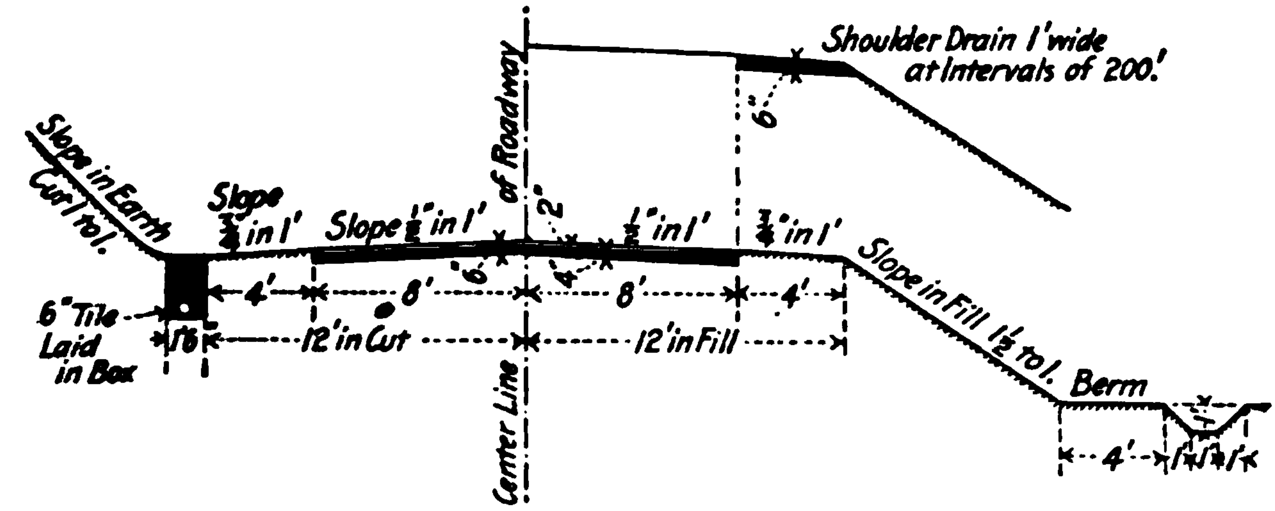
Local Stone — Lower course, No. 1 stone, 17 tons. Upper course, No. 2 stone, 15 tons; screenings for binder, 6 tons.

Total tonnage per 100′: Trap, 42; Local, 38.

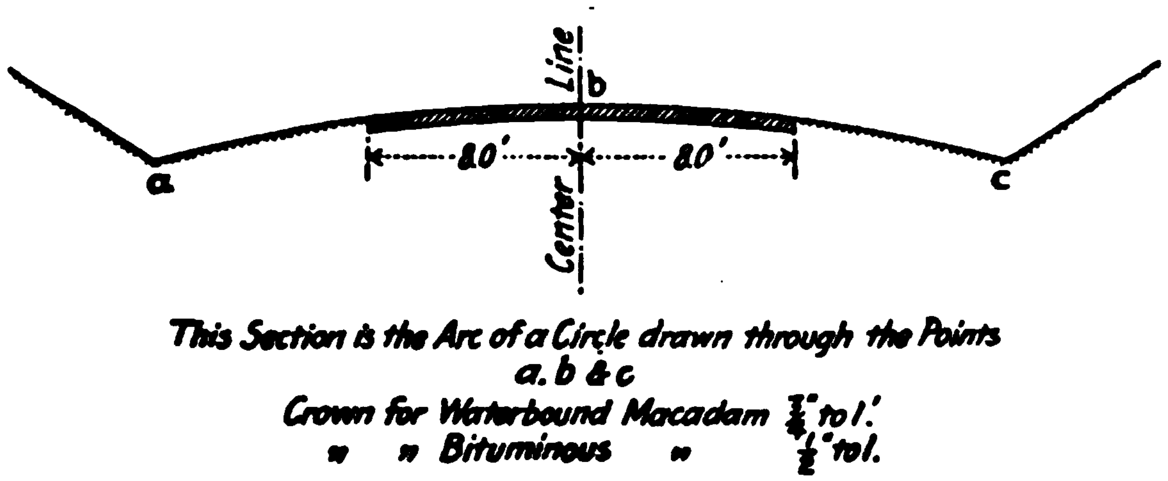
NOTE. — Condition No. 1: Bituminous Treatment — Penetration — lower course bound with stone screenings or sand.

Condition No. 2: Bituminous Treatment — Surface Spraying — screenings of sand binder in upper course.

PLATE 3



State of Washington Standard Section



New Jersey Standard Section

Plates Nos. 1, 2, and 3 show some of the Standard Sections in use at the present time.

Widths of metaling can be discussed at this point, leaving depths for the chapter on "Foundations." There are two sets of widths in general use, 12 ft., 15 ft., 20 ft. and 14 ft., 16 ft., 20 ft.

20 ft. widths are not often required and it is evident that the use of 12 ft. instead of 14 ft. or 15 ft. instead of 16 ft. means a large saving

(see footnote)[1] and is good policy provided the narrower width serves the purpose. There are two ways of approaching this problem. The first is to build the strong metaling just wide enough to comfortably take the heavy traffic, and if the natural shoulder material is not suitable, treat the shoulders to a width of 14′–20′ with gravel, waste #2 stone, or #3 stone filled and rolled but not puddled or tarred, making them suitable and wide enough for the light "turn out traffic"; this method results in the 12′ and 15′ widths. The second way is to make the full depth of the macadam just wide enough to allow two vehicles to pass with a minimum safe clearance, not giving the shoulders any special treatment. This method results in the 14′ width on unimportant roads. The 16′ width is harder to justify, as on the main traveled roads it is wider than necessary for the heavy travel and too narrow for the automobile "turn out traffic."

In the writer's opinion 12′ should be used in preference to 14′ on the side roads where the shoulder material is good or where gravel is cheap or local crushed stone is used, making it possible to get cheap #2 or #3 stone; the 14′ width should be used in preference to 12′ where the shoulder material is bad and gravel or stone are imported. On the main roads 15′ is as satisfactory as 16′ and is cheaper under all conditions, because the 16′ width does not overcome the necessity for a good shoulder.

The importance of shoulder treatment on the side roads should not, however, be overestimated. One of the New York State Highway engineers made a trip from Albany to Binghamton (130 miles) in the Fall of 1910 and counted the rigs he passed; they averaged one every four miles outside of the villages; from this it would seem that for roads of this class shoulder treatment is not worth while unless fine shifting sand or heavy clay is encountered.

The sketches given below show a number of variations of section for bituminous macadam which are applicable to special conditions. Figure 3 shows the distribution of stone on unimportant road sections.

Figure 4 gives a good typical section for ordinary conditions on a main road.

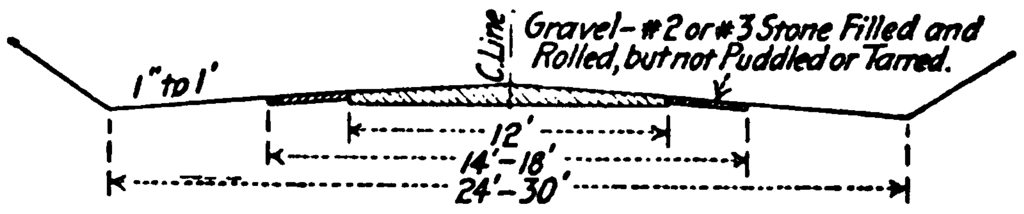


FIG. 3. — Bituminous Macadam

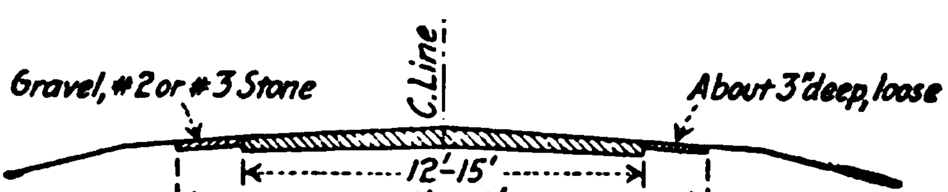


FIG. 3 A. — Shoulder Treatment

[1] *The amount saved per mile,* assuming a depth of macadam of 6″ and an average *price of stone at $3.50* per cu. yd. in place would be approximately $700.00 for use *of 12′ in place of 14′* and $350.00 for use of 15′ in place of 16′.

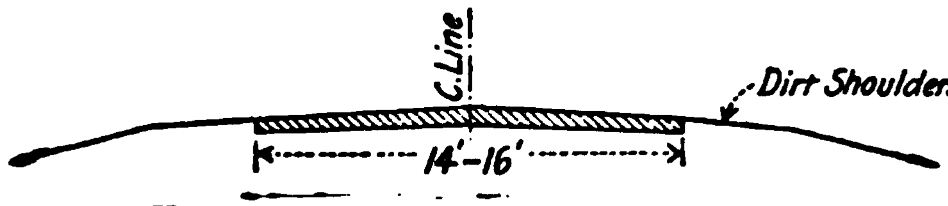


FIG. 3 B. — No Shoulder Treatment

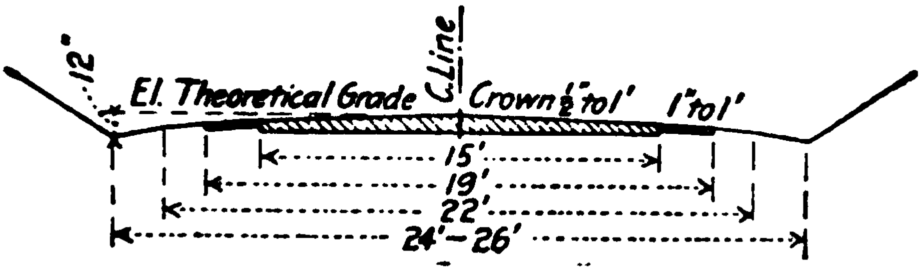


FIG. 4. — Bituminous Macadam

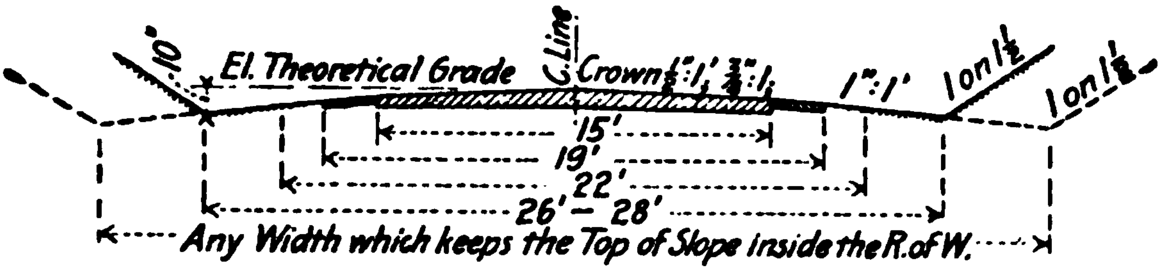


FIG. 5

Figure 5 shows a section adapted to the top of hills where a small amount of surface water is expected. If for any reason it is not practicable to cut into the hill beyond a certain depth and more dirt is needed for fill than is given by the 26′ section at this depth, the shoulders can be widened, provided the tops of the slopes keep within the right-of-way. It is always best to use as shallow a ditch as possible, as it simplifies the construction and maintenance of entrances to the abutting properties.

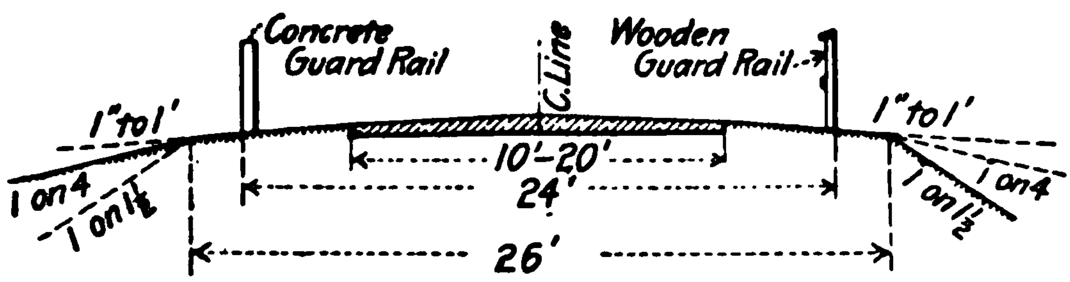


FIG. 6

Figure 6 gives a section showing the variations in fill. A slope of 1″ to 1′ beyond the 22′ width is used on shallow fills; a side slope of 1 on 4 is used for all ordinary fills up to a 7′ depth; beyond a 7′ depth it is cheaper to erect and maintain guard-rail, using a 1 on 1½ slope. The cost of guard-rail is taken up under "Minor Points."

The section shown in Figure 7 is used for unusually heavy cuts to keep the excavation down as much as possible; it should never be used on a *sharp curve* because of the difficulty in seeing ahead. (See *Alignment, page 17*, and Office Practice, page 181.)

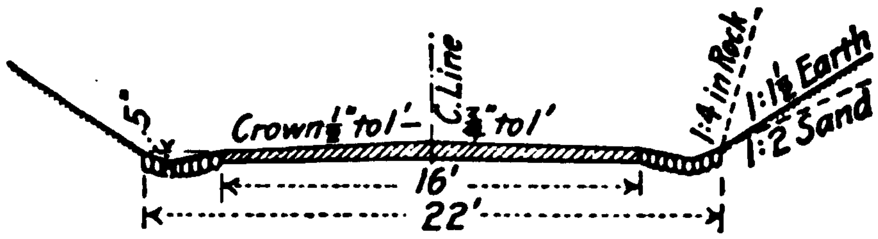


FIG. 7

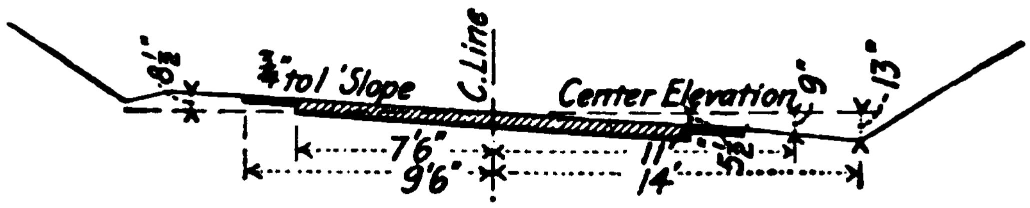


FIG. 8. — Banked Section in Excavation

Figure 8 shows a section well suited for sharp curves on steep grade the slope of ¾" to 1' is not objectionable for slow traffic up the hi and makes easier riding for vehicles traveling rapidly down grad this section has also been used successfully on sharp curves on lev grades and is becoming a standard feature of the New York Sta work.

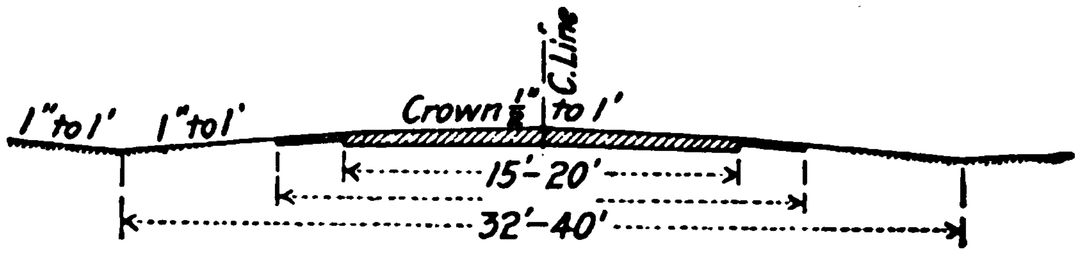


FIG. 9

Figure 9 is a satisfactory village section and by the use of a variab width can be made to fit conditions on most streets.

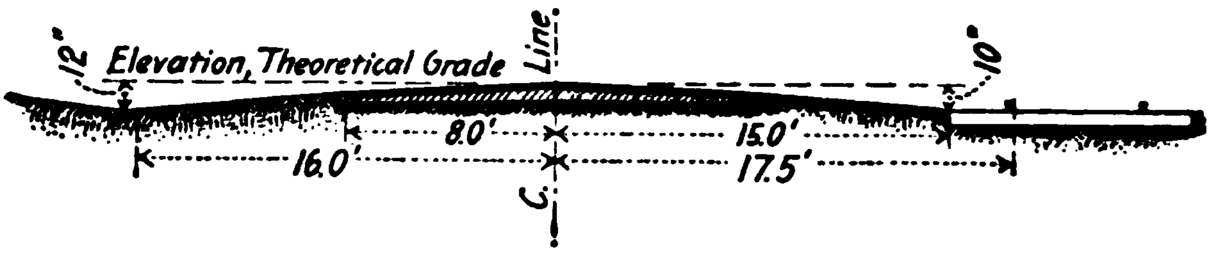


FIG. 10. — Bituminous Macadam Tracks on Side

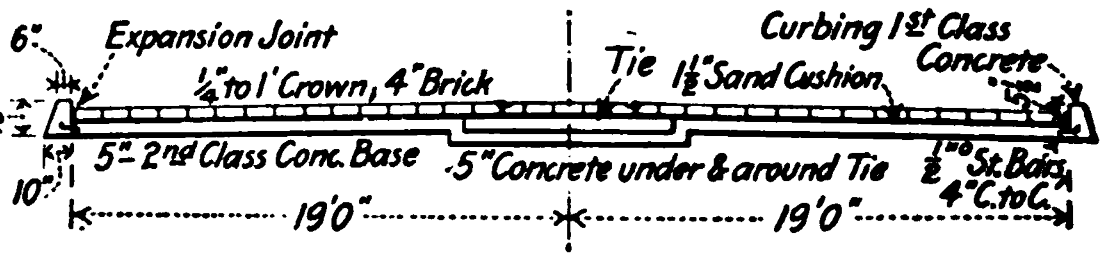


FIG. 10 A. — Village Street, Brick Pavement. Tracks in center, "T Rail Special Grooved Brick

The preceding discussion attempts to show only the main poin *to be considered,* for every road presents local conditions peculiar

itself that require special solutions. However, if the Engineer keeps these points in mind, he will make an economical and appropriate design.

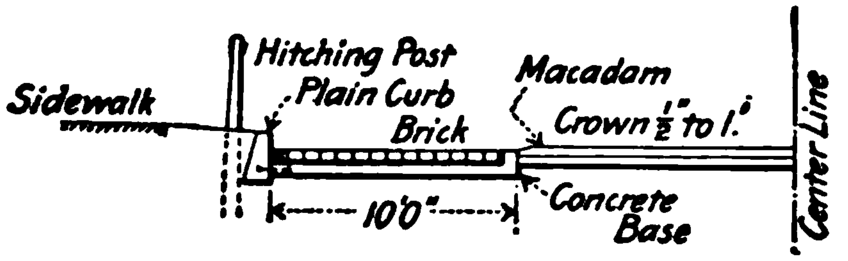


FIG. 11. — Village Section. Combined Brick and Macadam Section in Front of Stores, where Horses will be Hitched Close to the Curb. Prevents Pawing up the Macadam

It may be said in closing that many of the road widths, as actually built, do not represent the engineering judgment of the Highway Departments. On a road where it is evident that a 12′ or 14′ width of metaling would amply serve the traffic there is often a strong sentiment that this locality is being defrauded because some other road is 16′ wide, and if political influence can be successfully used a 16′ width is constructed. This is mentioned to show one of the practical difficulties in attempting to build an *economical* road that meets the actual traffic requirements. The general complaint that roads are becoming more expensive overlooks this contributory cause, and, while it is true that more expensive constructions are necessary on account of changed traffic conditions, it can be safely asserted that in most cases where political expediency overrules engineering judgment, either in regard to widths or materials, an unnecessary expense is incurred. This condition is, however, sometimes due to defects in the Highway laws which allow too much interference by local officials who are not qualified to judge in such matters, and it has been demonstrated that better results are obtained by centralizing the control of the design, particularly in regard to widths, alignment, and materials, in some executive or commission, which is as independent as possible of such local pressure.

CHAPTER III

CULVERTS — SMALL SPAN BRIDGES — UNDER DRAINS

This chapter deals with the smaller drainage structures only. For the theory and practice of reinforced concrete long-span structures, masonry arches, or steel bridges, the reader is referred to the standard works on those subjects.

The conditions for transverse surface drainage to the ditches were given in chapter II and the minimum ditch grades that insure the longitudinal drainage were mentioned under the heading of "Minimum Grades," page 11. Ditches on steep grades must be protected from wash by cobble paving, cement gutters, or loose stone, and these designs are considered under "Minor Points," page 92.

I. Culverts

Engineers do not differ much in the design of these structures. They should be permanent; should be large enough to take the maximum flood flow; should, if possible, be self-cleaning; must admit of being cleaned easily, when necessary, and must be long enough to include the normal width of section between parapets. There is nothing more unsightly and dangerous than to have the width of roadway narrowed at a culvert.

Cast-iron pipe or reinforced concrete boxes are generally used. Cast-iron pipe culverts larger than 18″ are rarely designed, as they are not economical. (See Table No. 17, page 57.) Vitrified pipe should never be placed under the roadbed proper unless encased in concrete; even then cast-iron pipe is preferable and probably cheaper. Where the head room is small, usual practice calls for cast-iron pipe, and if the flow is large, a double or triple line of pipe may be constructed. For small drainage areas the size of the culvert is determined by the convenience of cleaning, rather than by the discharge capacity. Where sufficient fall can be obtained to make it self-cleaning, a 12″ pipe is feasible, but where the flow is sluggish, nothing less than a 16″ or 18″ pipe will serve satisfactorily.

The self-cleaning velocity of flow for sand and earth particles is about one foot per second; for coarse gravel about three feet per second (Ogden's Sewer Design, page 134). A pipe laid on a slope that gives a velocity of five feet per second when flowing one-quarter full should keep clean; this requires a fall of approximately two feet in one hundred for a 12″ pipe, and is the minimum grade at which the 12″ size should be used.

For the smaller concrete culverts the shape of the opening should be designed to allow the use of collapsible forms.

The desired size of a culvert is usually determined in the field by *noting the dimensions* of the old culvert, if any, and by inquiries of *the neighboring residents* and the road commissioner as to how the

existing structure has handled the water in the past; any such conclusion should be checked by computing the probable maximum run-off from the area tributary to the culvert. For the convenience of designers, Table No. 10 is given, showing the approximate maximum run-off for small watersheds in flat, rolling, and hilly country. Of course, it is understood that such a table is to be used simply as a guide for judgment.

TABLE 10. MAXIMUM RUN-OFF FOR SMALL WATERSHEDS USING DICKENS' FORMULA

$D = C\sqrt[4]{M^3}$. RUN-OFF EXPRESSED IN SECOND FEET

Area in Square Miles	Flat Country C 200	Rolling Country C 250	Hilly Country C 300
0.1 = 64 acres	36	45	54
0.2	60	75	90
0.3	81	101	121
0.4	100	125	150
0.5	119	149	180
0.6	136	170	204
0.7	153	191	229
0.8	169	211	253
0.9	185	231	277
1.0	200	250	300
2.0	334	417	501
3.0	456	570	684
4.0	564	705	846
5.0	668	835	1002
6.0	764	955	1146
7.0	860	1075	1290
8.0	950	1188	1426
9.0	1038	1297	1556
10.0	1122	1402	1682
20.0	1890	2362	2834
30.0	2560	3200	3840
40.0	3180	3975	4770
50.0	3760	4700	5640
60.0	4310	5400	6480
70.0	4840	6050	7260
80.0	5360	6700	8040
90.0	5840	7300	8760
100.0	6320	7900	9480

For areas under 0.1 square mile, see Table 12.

Dickens' formula takes into consideration the rate of rainfall a character of the catchment basin by the coefficient "C" and is reliable as any of the maximum run-off formulæ. Wilson in "Irrigation Engineering," page 19, gives the following values of "C

Rainfall 3.5 to 4 inches in 24 hours.

Flat country	C	200
Mixed "	C	250
Hilly "	C	300

These values are safe the Northern and East Atlantic States.

Rainfall 6 inches in 24 hours.

Flat country	C	300
Mixed "	C	325
Hilly "	C	350

TABLE 11. NEW YORK CENTRAL AND HUDSON RIVER R.R. CU VERTS FOR SMALL DRAINAGE AREAS

Steep, Rocky Ground. Acres	Flat Cultivation, Long Valley. Acres	Size. Diameter in Inches	Equivalent Capacity. Pipes
5	10	10″	
10	20	12″	
20	40	16″	
25	50	18″	two 16″ pipes
30	60	20″	two 16″ pipes
45	90	24″	two 18″ pipes
70	140	30″	two 24″ pipes
110	220	36″	two 30″ pipes
150	300	42″	two 30″ pipes
180	360	48″	two 36″ pipes
280	560	60″	

NOTE. — To be used only in the absence of more reliable info mation, particularly existing culverts over the same stream.

TABLE 11 A. CULVERT DESIGN. IOWA STATE HIGHWAY CO MISSION[1]

Size of Culvert Opening	Maximum Acres	Minimum Acres
2′ × 2′	70	28
4′ × 4′	376	140
6′ × 6′	1300	520
8′ × 8′	2700	1120
10′ × 10′	5000	2000

Types of Structures Used[1]

1. Box culverts and slab bridges 2′ to 20′ span. Not economical over 20′ span.
2. Reinforced concrete arches 8′ to 100′. Constant tendency to destroy by temperature strains and settlement.
3. Pony truss steel bridges. 30′ to 80′ span with reinforced concrete floor. Adapted to districts where concrete materials are scarce.
4. Reinforced concrete girders, 20′ to 50′ span. Very economical, but require careful design. Not economical for spans over 50′.

Where the road runs through a village, a closer computation may be obtained by using a sewer run-off formula.

The Burkle-Ziegler formula for such approximations is as follows:

$$\left.\begin{matrix}\text{Cubic ft. per sec.}\\ \text{per acre reaching}\\ \text{culvert}\end{matrix}\right\} = C \times \left\{\begin{matrix}\text{Av. cu. ft. of}\\ \text{rainfall per sec.}\\ \text{per acre during}\\ \text{heaviest fall}\end{matrix}\right\} \times \sqrt[4]{\frac{\text{Av. slope of ground in ft. per 1000}}{\text{No. of acres drained}}}$$

$C = 0.75$ for paved streets and built up business blocks.
$C = 0.625$ for ordinary city streets.
$C = 0.30$ for villages with gardens, lawns, and macadamized streets.

Trautwine states that 1″ of rainfall per hour equals 1 cu. ft. per second per acre approximately.

For drainage areas of under 1 square mile, it is probably better to use the Burkle-Ziegler formula even for farming country, using the coefficient $C = 0.25$.

Table 12 shows the amount of run-off computed by this formula assuming a maximum rainfall rate of 4″ per hour for the constants $C = 0.30$ and $C = 0.25$ for areas up to 1 square mile.

NOTE: — Quantities in Tables 10, 12, and 13 computed and checked by slide-rule; sufficiently accurate for the purpose for which these tables are intended.

Table 13 gives the velocity of flow and the discharge capacity of pipe and box culverts for different rates of fall per 100 feet.

Examples of the use of tables 10 to 13 in checking culvert sizes.

1. Determine the character and area of watershed tributary to culvert; say rolling country, one square mile.
2. Determine flood flow for this area of rolling country from Table No. 10; equals 250 second feet.
3. From the profile of the stream where it crosses the road determine the fall in feet per 100; say 1.0 ft.
4. In Table 13 opposite 1.0 ft. in the "Rate of Fall" column, pick out the size that has a discharge capacity of 250 second feet; equals 4′ x 4′ culvert.

Where the road runs through a depression which has no outlet, a culvert should be placed at the lowest point to keep the water at the same elevation on both sides of the road, and the grade line raised above high-water level.

It is our opinion that a culvert should have the same slope as the stream bed. If given a greater slope the outlet end tends to clog, *and if a lesser the inlet* end will plug. It is unusual for culverts to *fill badly, except when pl*aced at the foot of a steep hill where th

[1] See Table at foot of p. 34.

stream velocity is naturally reduced. At such points an extra large structure should be designed with the idea of providing sufficient waterway even after the contraction caused by this settlement has occurred. Such a culvert should be cleaned after each freshet.

More trouble is experienced from culverts becoming filled with ice due to alternate freezing and thawing weather; this is particularly true of small culverts draining springs. Culverts as large as 2'x 2' have frozen solid in this manner, and if this condition is anticipated the size should be regulated accordingly or trouble will be experienced during the Spring break-up.

In designing culverts under side roads, the length must be great enough to provide an easy turn; many times a saving in length can be made by placing the culvert a short distance down the side road, as shown in figure No. 12, page 38.

Table 12. Run-off for Small Areas

Discharge in cu. ft. per second for a maximum rainfall rate of 4 inches per hour.

Area in Acres	Fall of 5' in 1000		Fall of 20' in 1000		Fall of 50' in 1000	
	C = 0.30	C = 0.25	C = 0.30	C = 0.25	C = 0.30	C = 0.25
1	1.8	1.5	2.5	2.1	3.1	2.7
2	3.0	2.5	4.2	3.5	5.4	4.5
3	4.1	3.4	5.7	4.8	7.2	6.0
4	5.0	4.2	7.2	6.0	9.0	7.5
5	6.0	5.0	8.5	7.1	10.7	8.9
6	6.8	5.7	9.7	8.1	12.2	10.2
7	7.7	6.4	10.9	9.1	13.7	11.4
8	8.5	7.1	12.0	10.0	15.1	12.6
9	9.3	7.8	13.2	11.0	16.5	13.8
10	10.1	8.4	14.3	11.9	18.0	15.0
20	16.9	14.1	24.0	20.0	30.2	25.2
30	23.0	19.2	32.5	27.1	40.7	33.9
40	28.5	23.8	40.3	33.6	50.9	42.4
50	33.6	28.0	47.7	39.8	60.0	50.0
60	38.6	32.2	54.6	45.5	68.7	57.3
70	43.3	36.1	61.4	51.2	77.3	64.4
80	48.0	40.0	67.9	56.6	85.2	71.0
90	52.4	43.7	73.9	61.6	93.1	77.6
100	56.7	47.3	80.2	66.8	100.8	84.0
200	95.4	79.5	134.6	112.2	169.7	141.4
300	129.0	107.7	182.9	152.4	229.7	191.4
400	160.0	133.6	227.0	189.2	285.6	238.0
500	190.0	158.0	268.0	223.5	336.6	280.5
600	216.0	180.0	307.0	256.0	387.3	322.8
640 } 1 sq. mile }	230.0	[1]192.0	323.0	269.0	406.3	338.6

[1] 200 second feet by Dickens' formula, Table 10.

Slope in Feet per 100	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.
0.5					4.5	6	5.0	9	5.4	12	5.8	15	6.1	19
1.0					6.8	9	7.0	11	7.7	17	8.2	21	9.2	29
2.0	7.4	6	8.3	9	9.2	13	10.0	18	10.9	24	11.5	30	12.3	39
3.0	9.2	7	10.3	11	11.2	16	12.2	21	13.4	29	14.2	37	14.8	46
4.0	10.6	8	11.8	12	13.1	18	14.2	25	15.3	34	16.5	43	17.2	54
5.0	11.8	9	13.3	14	14.6	20	16.2	28	17.3	38	18.0	48	19.0	60
6.0	13.0	10	14.6	15	16.2	25	17.5	31	19.0	41	20.0	53	21.3	67
Area Sq. Ft.	0.78		1.07		1.39		1.76		2.17		2.64		3.14	
Value of R	0.25		0.29		0.33		0.37		0.42		0.46		0.50	

CONCRETE BOXES

Slope in Feet per 100	2′ × 1.5′		2′ × 2′		3′ × 2′		3′ × 3′		4′ × 2′		4′ × 3′		4′ × 4′		5′ × 3′		5′ × 4′		5′ × 5′	
	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.	Vel.	Dis.
0.5	7.0	21	7.7	31	8.6	52	9.7	87	9.7	78	10.8	130	11.6	186	11.9	170	13.0	260	13.8	340
1.0	10.0	30	10.4	42	12.5	75	13.7	123	13.7	110	15.0	180	16.7	267	16.9	254	18.5	370	19.0	475
2.0	14.0	42	14.8	59	17.5	105	19.0	171	19.0	152	22.0	263	23.6	378	23.8	357	26.2	523	28.0	700
3.0	17.2	52	18.3	73	21.6	130	23.5	212	23.5	188	26.5	318	30.0	464	29.5	443				
4.0	20.0	60	21.0	84	24.8	149	27.5	248	27.0	216	30.5	366								
5.0	22.6	68	23.5	94	27.5	165	31.0	279	31.0	248										
6.0	24.0	72	26.0	104	30.0	180														
Area Sq. Ft.	3.0		4.0		6.0		9.0		8.0		12.0		16.0		15.0		20.0		25.0	
Value of R	0.60		0.66		0.86		1.0		1.0		1.2		1.33		1.36		1.54		1.66	

Note.—Table 13 is figured from Church's diagrams of Kutters formula using n = 0.011; the use of these diagrams for short culverts is approximate only but it is sufficiently close for the purposes for which this table is intended.

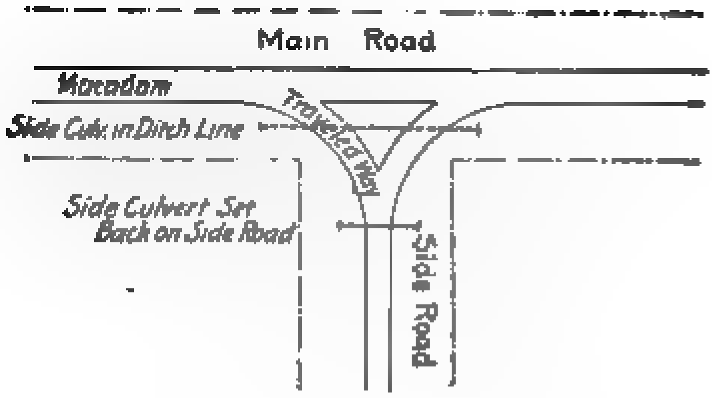


FIG. 12

The following section shows a form of culvert often used in village streets where deep ditches at the culvert site would be objectionable:

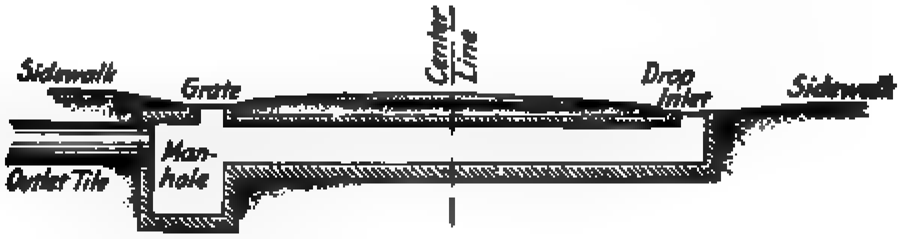


FIG. 13

For the small-sized structures required to carry ditch drainage under driveways vitrified tile well laid is as suitable as any style of construction; the wooden boxes built by some Departments are not economical, which is shown in the following estimate of relative cost of small culverts, given by A. R. Hirsch in Wisconsin Road Pamphlet No. 4:

Kind	Size of Opening	Length	First Cost and Maintenance for 100 Years
3″ Hemlock box	15 in. sq.	24′	$252.00
Concrete box	15 in. sq.	20′	40.00
Concrete pipe	18 in.	20′	35.00
Single strength V. T. P.	18 in.	30′	41.00
Double strength V. T. P.	18 in.	28′	42.00
Cast-iron pipe	18 in.	24′	166.00
Corrugated steel	18 in.	26′	196.00

SMALL SPAN, SOLID FLOOR BRIDGES

Under this head are included spans of 5 to 25 feet; they are generally designed from one of three types: reinforced concrete slabs,

steel I-beam stringers supporting thin reinforced concrete floor slabs, or plain and reinforced concrete arches.

Central piers will often reduce the cost of culverts having a long span with small height.

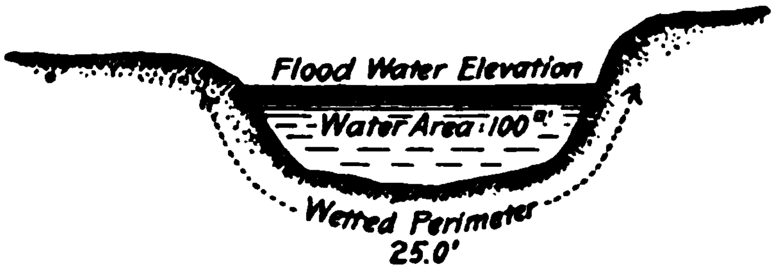
For structures of this class more care must be taken in determining the span and height. On streams requiring spans of more than 10 feet there are generally existing structures above and below the proposed bridge site which will afford the best basis for judgment. While it is usually good policy not to reduce the span of an existing structure it is often found that the present bridge, particularly if it is a steel bridge that has been sold to the town by an enterprising bridge company, has a needlessly long span.

If the freshet velocity of the stream is high the stream bed and the abutment foundations may be protected from scour by riprap. However, it is not often necessary to take this precaution for small span bridges. According to Trautwine a velocity of eight miles an hour, or 12′ per second, will not derange quarry rubble-stones exceeding half a cu. ft. deposited around piers or abutments. A rough approximation of small stream velocities can be made by assuming a value of 60 for the constant C in the formula $V = C\sqrt{RS}$ where V = velocity of flow in feet per second; constant C = 60.

$$R = \text{Hydraulic radius} = \frac{\text{Cross sectional area of flow}}{\text{Wetted Perimeter.}}$$

S = slope of stream.

Example. To approximate the freshet velocity of the stream shown having a fall of 1.0′ per 100′, or 53′ per mile



$$V = C\sqrt{RS}$$

$$C = 60$$

$$R = \frac{100}{25} = 4$$

$$S = \frac{1}{100} = 0.01$$

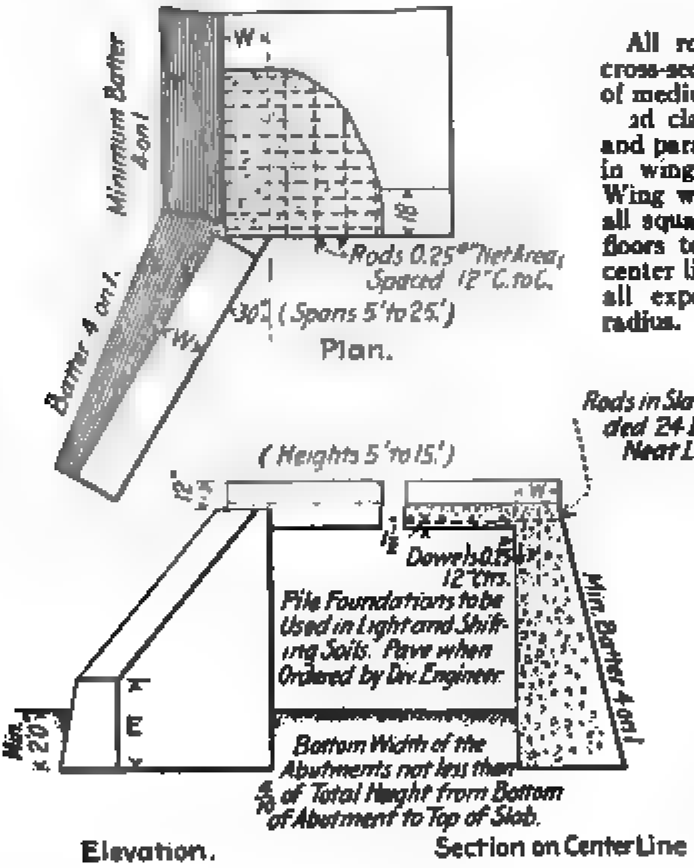
$$V = 60\sqrt{4 \times 0.01} = 60\sqrt{.04} = 60 \times .2 = 12 \text{ ft. per second.}$$

Plates No. 4 to No. 6 c show the standards for culverts and small bridges as used by various State Departments.

Under Drainage

The purpose of under drains is to intercept the ground water before it reaches and softens the subgrade. On a side hill road the drain is usually placed under the ditch on the up-hill side (see Figure No. 14, *position No. 1, page 51*), where the greatest depth can be obtained

Plate 4.— New York State Slab Bridges



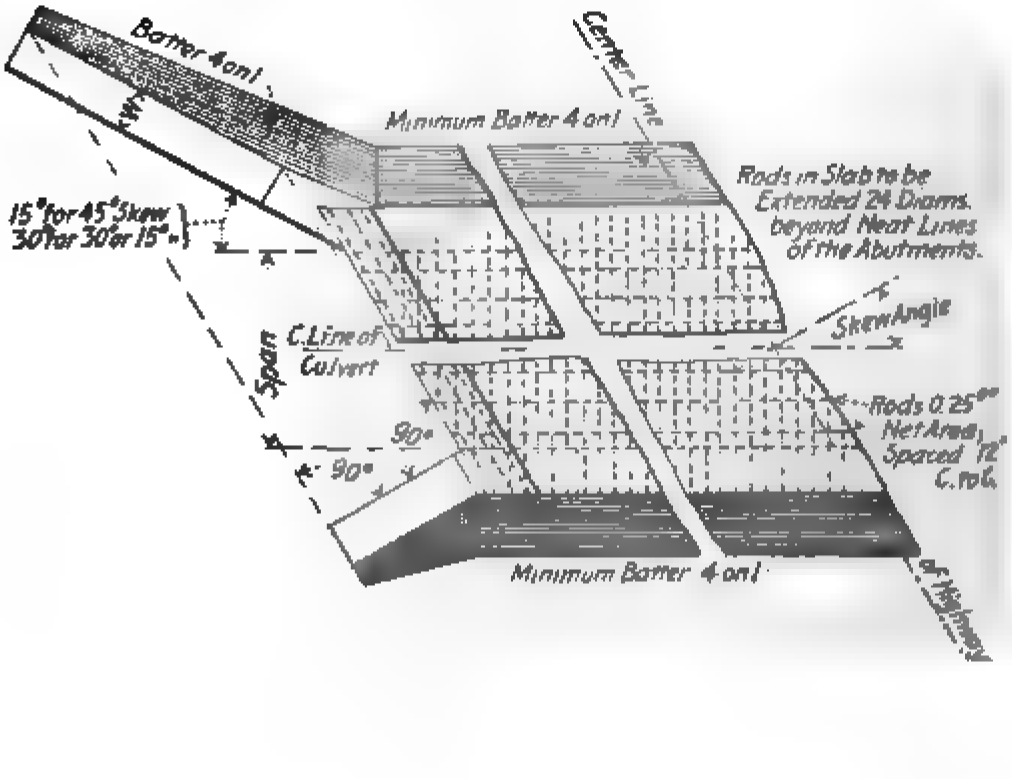
Note

All rods to have a deformed cross-section. All rib metal to be of medium steel.

2d class concrete in all slabs and parapets 3d class concrete in wings invert and abutments. Wing walls on the outlet end of all square culverts with concrete floors to be built parallel to the center line of the culvert. Round all exposed edges to 1½ inch radius.

For Typical Section "F"

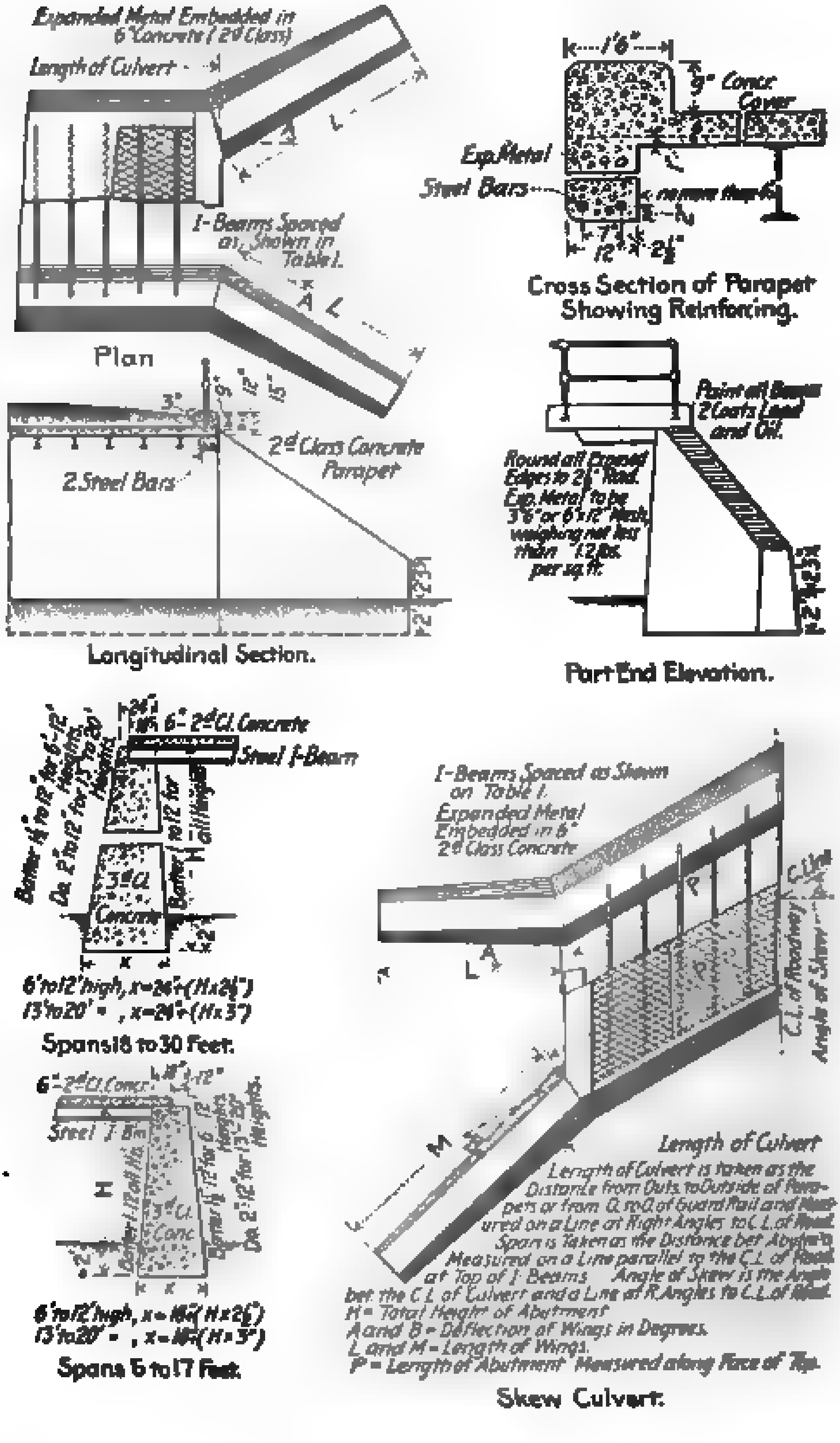
Where culvert covers become a part of concrete base for brick pavement, transverse reinforcement should be extended 12" beyond back of abutment into concrete base.



Span	Thickness of Slab	Net Area of Rods	Rod Spacing C–C	Length of Dowels
5	8″	0.25sq.″	4½″	12″
6	9″	"	4″	"
7	10″	0.39sq.″	5¾″	"
8	10″	"	5¼″	"
9	11″	"	5″	"
10	12″	"	4¾″	"
11	12″	0.56sq.″	6¼″	"
12	13″	"	6″	18″
13	13″	"	5¾″	"
14	14″	"	5⅜″	"
15	14″	"	5″	"
16	15″	"	4¾″	"
17	15″	"	4¾″	"
18	16″	"	4½″	"
19	17″	"	4¼″	"
20	18″	0.77sq.″	5¼″	"
21	18″	"	5¼″	"
22	19″	"	5″	24″
23	19″	"	5″	"
24	20″	"	4⅝″	"
25	21″	1.00sq.″	5⅞″	"

For Spans 5′ to 19′ W = 18″ For Clear Height 10′ or less
" " 5′ to 19′ W = 24″ " " " 11′ to 15′
" " 20′ to 25′ W = 24″ " " " 15′ or less
For Clear Height 7′ or less E = 3′- 0″
" " " 8′ to 10′ E = 4′- 0″
" " " above 10′ E = 5′- 0″

PLATE 4 A. — New York State I-Beam Bridges



QUANTITIES IN CULVERTS

Culverts	15° Skew	30° Skew	45° Skew	Steel I-Beams: Depth Inches	Steel I-Beams: Spacing	Steel I-Beams: Length feet	Steel I-Beams: Wt per ft.	Steel I-Beams: Wt. of Beam	Steel Bars: Size	Steel Bars: Weight of 4 Bars	Sq. feet E'x'p'd Met: 25 foot Length	Sq. feet E'x'p'd Met: Per foot Length	Cu. Yds. 2d Class Concrete Cover and Parapets: 25 foot Length	Cu. Yds. 2d Class Concrete Cover and Parapets: Per foot Length	Ft. B. M. Lumber: 25 foot Length	Ft. B. M. Lumber: Per foot Length	Pounds Spikes and Nails	Lin ft Bridge Rail	Lin. ft. Pipe Rail
6	5.80	5.20	4.24	6		8	12½	100	⅞"	61	200	8	4.54	0.15	855	30	24	20	16
7	6.76	6.06	4.95	7		9	15	135	⅞"	69	225	9	5.08	0.17	952	33	26	22	18
8	7.73	6.93	5.66	7		10	15	150	⅞"	76	250	10	5.63	0.19	1042	36	28	24	20
9	8.69	7.79	6.36	8	2'-9"	11	18	198	⅞"	84	275	11	6.63	0.20	1143	39	30	26	22
10	9.66	8.66	7.07	9	3'-0"	12	21	252	⅞"	92	300	12	7.28	0.22	1234	42	32	28	24
11	10.63	9.53	7.78	9	3'-0"	13	21	273	⅞"	135	325	13	7.88	0.24	1325	45	34	30	26
12	11.59	10.39	8.40	9	2'-6"	14	21	294	⅞"	146	350	14	8.48	0.26	1431	48	36	32	28
13	12.56	11.26	9.19	10	1'-0"	15	25	375	1"	204	375	15	9.16	0.28	1523	51	38	34	30
14	13.52	12.12	9.90	10	2' 9"	16	25	400	1"	218	400	16	9.78	0.30	1635	54	40	36	32
15	14.49	12.90	10.01	12	3'-0"	17	31½	535½	1"	231	425	17	10.56	0.31	1727	57	42	38	34
16	15.45	13.80	11.31	12	3' 0"	18	31½	567	1"	245	450	18	11.19	0.33	1820	60	44	40	36
17	16.42	14.72	12.02	12	3'-0"	19	31½	598½	1⅛"	327	475	19	11.81	0.35	1956	63	46	42	38
18	17.39	15.59	12.73	12	3' 0"	21	31½	661½	1⅛"	361	525	21	12.90	0.39	2052	66	48	44	40
19	18.35	16.46	13.44	12	2'-9"	22	31½	693	1⅛"	378	550	22	13.51	0.41	2148	69	50	46	42
20	19.32	17.52	14.14	15	1' 0"	23	42	966	1⅛"	396	575	23	14.51	0.43	2244	72	52	48	44
21	20.28	18.19	14.85	15	3'-0"	24	42	1008	1⅛"	510	600	24	15.14	0.44	2340	75	54	50	46
22	21.26	19.05	15.56	15	3' 0"	25	42	1050	1⅛"	531	625	25	15.79	0.46	2519	78	56	52	48
23	22.22	19.92	16.26	15	3'-0"	26	42	1092	1⅛"	552	650	26	16.43	0.48	2618	81	58	54	50
24	23.18	20.78	16.97	15	3'-0"	27	42	1134	1⅛"	694	675	27	17.08	0.50	2718	84	60	56	52
25	24.15	21.65	17.68	15	2'-9"	28	42	1176	1⅛"	720	700	28	17.73	0.52	2818	87	62	58	54
26	25.11	22.52	18.38	15	2'-6"	29	42	1218	1⅛"	887	725	29	18.36	0.54	2918	90	64	60	56
27	26.08	23.38	19.00	18	3'-0"	30	55	1650	1⅛"	918	750	30	19.50	0.56	3018	93	66	62	58
28	27.05	24.25	19.80	18	3'-0"	31	55	1705	1⅛"	940	775	31	20.16	0.57	3222	96	68	64	60
29	28.01	25.11	20.51	18	3'-0"	32	55	1760	1⅛"	970	800	32	20.82	0.59	3326	99	70	66	62
30	28.98	25.98	21.23	18	3' 0"	33	55	1815	1⅛"	1010	825	33	21.48	0.61	3430	103	72	68	[illegible]

NOTE. Length of [illegible] in Parapets same as lengths of I-Beams

PLATE 4A — *continued*

Height of Abutment	*Table No. 2* Lengths of Wings		STRAIGHT A = 30° B = 30° Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culvert more or less than 25 ft.		*Table No. 3* Lengths of Wings		15° SKEW A = 30° B = 15° Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culvert more or less than 25 ft.	
H	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry
6	3.87	3.87	23.3	5.5	28.5	6.5	0.94	1.17	3.51	3.67	24.2	5.2	29.7	6.1	0.98	1.21
7	5.60	5.60	28.3	9.2	34.3	10.9	1.17	1.41	5.06	5.40	29.6	8.8	36.0	10.4	1.20	1.47
8	7.33	7.33	34.0	13.8	40.5	16.4	1.38	1.68	6.62	7.13	35.4	12.9	42.7	15.5	1.44	1.74
9	9.06	9.06	40.0	19.4	47.3	22.7	1.63	1.95	8.16	8.86	41.6	18.3	49.6	21.6	1.69	2.03
10	10.79	10.79	46.4	25.4	54.5	30.2	1.88	2.25	9.72	10.59	48.2	24.3	57.2	28.8	1.95	2.33
11	12.52	12.52	53.3	33.4	62.3	39.1	2.16	2.56	11.27	12.32	55.2	31.7	65.1	37.1	2.24	2.66
12	14.26	14.26	60.8	47.1	70.5	49.1	2.44	2.89	12.82	14.06	62.5	39.9	73.5	46.6	2.54	3.00
13	15.99	15.99	72.2	55.5	84.7	64.3	3.01	3.49	14.38	15.79	76.8	53.0	88.4	61.3	3.12	3.62
14	17.72	17.72	81.5	68.4	94.2	78.5	3.37	3.89	15.53	17.52	86.0	64.5	98.6	74.4	3.50	4.04
15	19.45	19.45	91.0	82.4	104.2	94.0	3.75	4.31	17.48	19.25	95.7	78.4	109.3	89.6	3.89	4.47
16	21.18	21.18	101.0	98.2	114.5	111.4	4.15	4.74	19.11	20.98	106.0	93.7	120.5	106.3	4.31	4.92
17	22.92	22.92	111.1	115.9	125.3	130.7	4.56	5.19	20.58	22.72	110.1	110.1	131.8	124.5	4.74	5.39

PLATE 4 A — *continued*

Table No. 4			30° SKEW A = 30° B = 15°						*Table No. 5*		45° SKEW A = 45° B = 0°					
Height of Abutment	Lengths of Wings		Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culverts more or less than 25 ft.		Lengths of Wings		Cubic Yards Third Class Concrete		Cubic Yards Third Class Masonry		Cubic Yds. each ft. in length of Culvert more or less than 25 ft.	
H	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry	L	M	2 Abut's	4 Wings	2 Abut's	4 Wings	Concrete	Masonry
6	3.4	4.44	27.0	5.6	33.3	6.8	1.09	1.35	3.6	4.24	33.0	5.5	40.5	6.8	1.34	1.65
7	4.9	6.56	32.8	8.8	40.2	11.3	1.33	1.63	5.1	6.36	40.5	9.7	49.5	11.2	1.63	2.00
8	6.4	8.69	39.5	14.4	47.6	17.0	1.59	1.94	6.6	8.49	48.3	14.5	58.8	17.1	1.95	2.37
9	7.9	10.81	46.3	20.2	55.7	23.8	1.87	2.26	8.1	10.81	57.0	20.3	68.5	23.8	2.29	2.76
10	9.4	12.93	53.7	26.9	64.0	31.7	2.17	2.60	9.6	12.73	66.0	27.2	78.5	31.8	2.66	3.18
11	10.9	15.05	61.6	34.7	72.9	40.9	2.48	2.95	11.1	14.85	75.4	35.0	89.2	41.0	3.04	3.63
12	12.4	17.17	70.0	43.7	82.3	51.4	2.82	3.34	12.6	16.97	85.5	44.1	100.5	51.4	3.46	4.09
13	13.9	19.30	85.7	58.3	99.2	67.5	3.48	4.03	14.1	19.10	105.0	58.8	121.5	67.9	4.26	4.94
14	15.4	21.42	96.0	71.4	110.7	82.8	3.89	4.40	15.6	21.22	117.6	71.8	135.3	83.0	4.76	5.50
15	16.9	23.54	107.0	86.4	122.4	99.5	4.33	4.97	17.1	23.54	130.8	87.1	149.8	99.4	5.31	6.09
16	18.4	25.66	118.0	102.9	134.6	117.3	4.79	5.48	19.6	25.46	144.7	103.6	165.0	117.4	5.87	6.71
17	19.9	27.78	129.7	121.2	147.0	137.2	5.27	6.00	20.1	27.58	159.0	121.6	180.6	137.8	6.46	7.35
18	21.4	29.90	142.0	141.1	160.5	159.7	5.77	6.54	21.6	29.70	173.0	141.8	197.0	159.7	7.08	8.02
19	22.9	32.02	154.6	163.5	174.0	184.4	6.30	7.11	23.1	31.82	189.6	164.1	213.9	184.7	7.72	8.71
20	24.4	34.14	168.0	188.5	188.0	211.2	6.84	7.70	24.0	33.94	206.0	189.1	232.0	211.6	8.39	9.43

Plate 4 A — *continued*

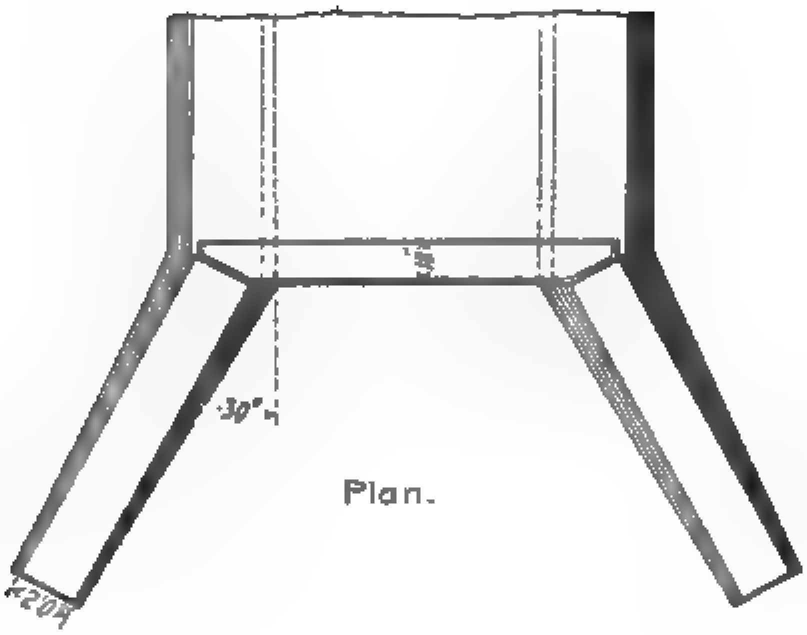
Table No. 6	Number I-Beams For Concrete Covers only			P = Length of Abutments		
	Spacing					
Length of Culvert	2'-6"	2'-9"	3'-0"	15° Skew	30° Skew	45° Skew
18	5	5	4	18.64	20.79	25.46
19	5	5	5	19.67	21.94	26.97
20	6	5	5	20.71	23.09	28.28
21	6	6	5	21.74	24.25	29.70
22	6	6	5	22.78	25.40	31.11
23	7	6	6	23.81	26.66	32.53
24	7	6	6	24.85	27.71	33.94
25	7	7	6	25.88	28.87	35.36
26	8	8	7	26.92	30.02	36.77
27	8	8	7	27.95	31.18	38.18
28	9	8	7	28.99	32.33	39.60
29	9	8	8	30.02	33.49	41.01
30	9	9	8	31.06	34.64	42.43
31	10	9	9	32.09	35.80	43.84
32	10	9	9	33.13	36.95	45.26
33	11	10	9	34.16	38.10	46.67

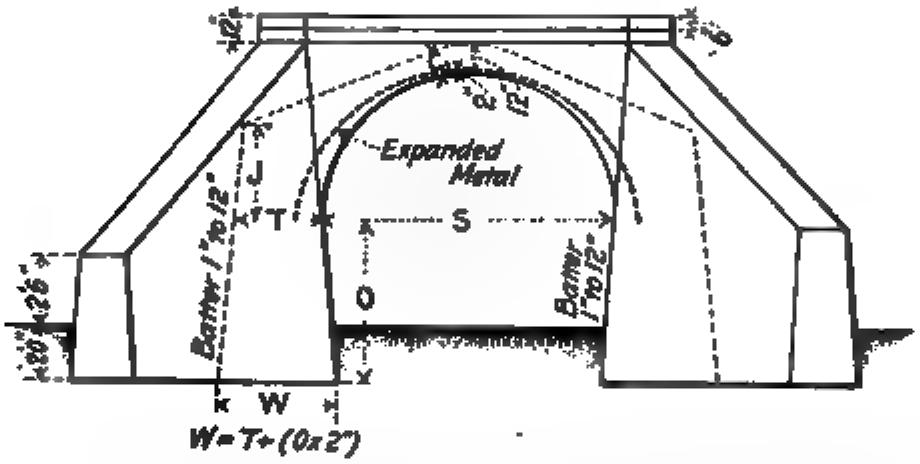
Application of Tables

Quantities for a 30° Skew Concrete Culvert, concrete top, length 30 feet, opening 13 feet high and 12 feet wide. From Table 1, an opening 12.12 ft. wide 30° Skew is a 14-ft. span requiring (see 30-ft. length, Table 6) 9 I-Beams spaced 2'-9" c. to c. (9 × 400) = 3600 lbs. I-Beams; 218 lbs. Bars; 400 + (5 × 16) = 480 sq. ft. Ex'p'd Metal; 9.78 + (5 × 30) = 11.28 cu. yds. 2d class Concrete 32 lin. ft. Pipe Rail. An opening 13 ft. high will require Abutments, 16 ft. high (13' + 2' in ground + 10" I-Beam = 15'-10"). From Table 4, Abutments = 118.0 cu. yds., Wings = 102.9 cu. yds. (5 × 4.79 = 23.95 cu. yds. 5 ft. extra length of Culvert) 118.0 + 102.9 + 23.95 = 244.85 cu. yds. 3d Class Concrete.

For Spans of more than 17 feet, use Masonry Tables for Concrete Abutments and Wings.

PLATE 5



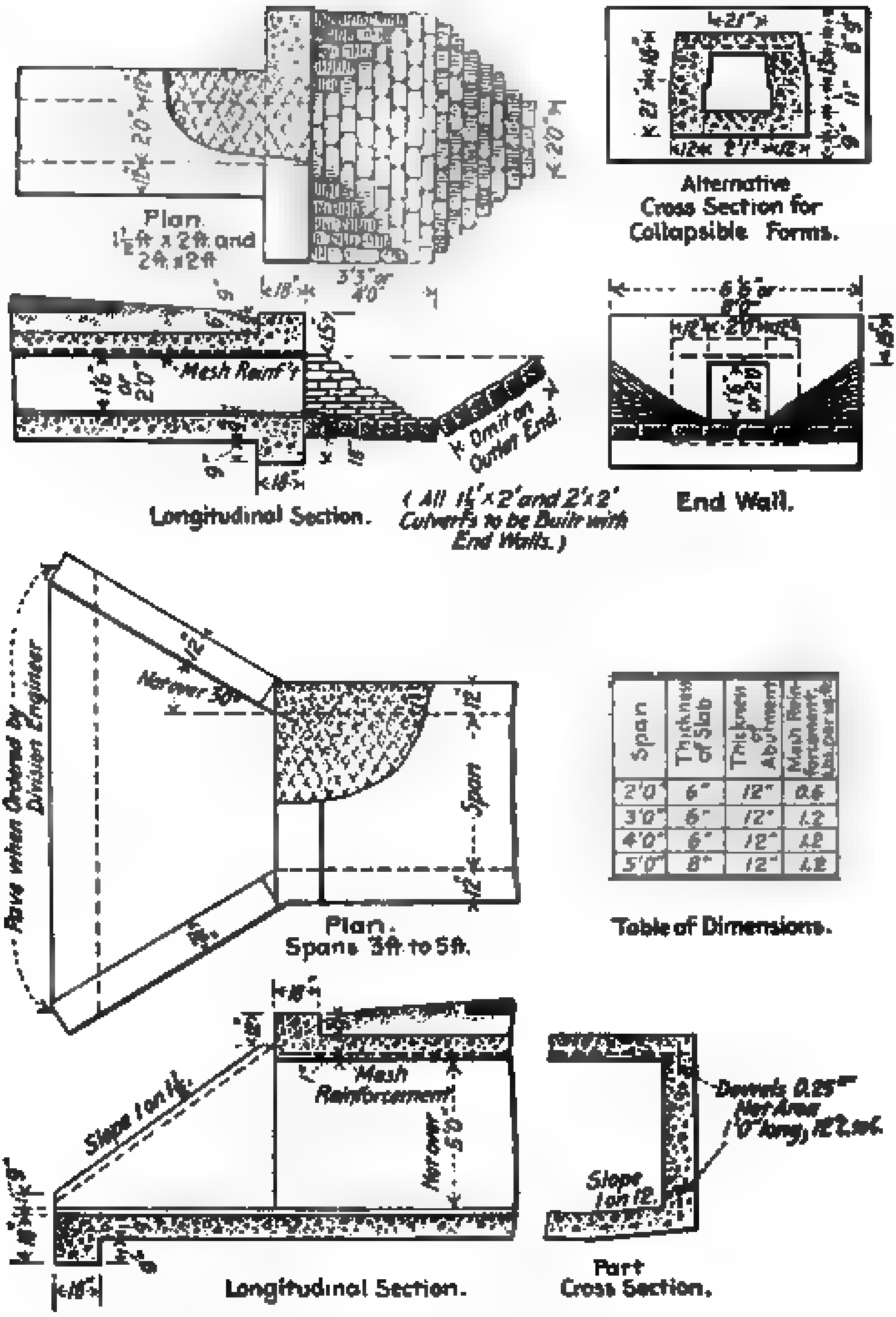


End Elevation.

GENERAL DIMENSIONS SEMI-CIRCULAR ARCH CULVERTS

S Span	Thickness at Springing Line		Thickness of Ring		Height of Haunch	
	T Concrete	K Masonry	C Concrete	R Masonry	J Concrete	V Masonry
6	2'-6"	2'-6"	10"	10"	1'-9"	2'-0"
8	2'-6"	2'-6"	11"	12"	2'-6"	2'-6"
10	3'-0"	3'-0"	12"	12"	3'-0"	3'-0"
12	3'-6"	3'-6"	14"	15"	3'-6"	3'-9"
14	3'-9"	3'-9"	15"	15"	4'-0"	4'-6"
16	4'-0"	4'-0"	16"	15"	4'-8"	5'-0"
18	4'-6"	4'-6"	18"	18"	5'-0"	5'-6"
20	5'-0"	5'-0"	18"	18"	5'-6"	6'-6"

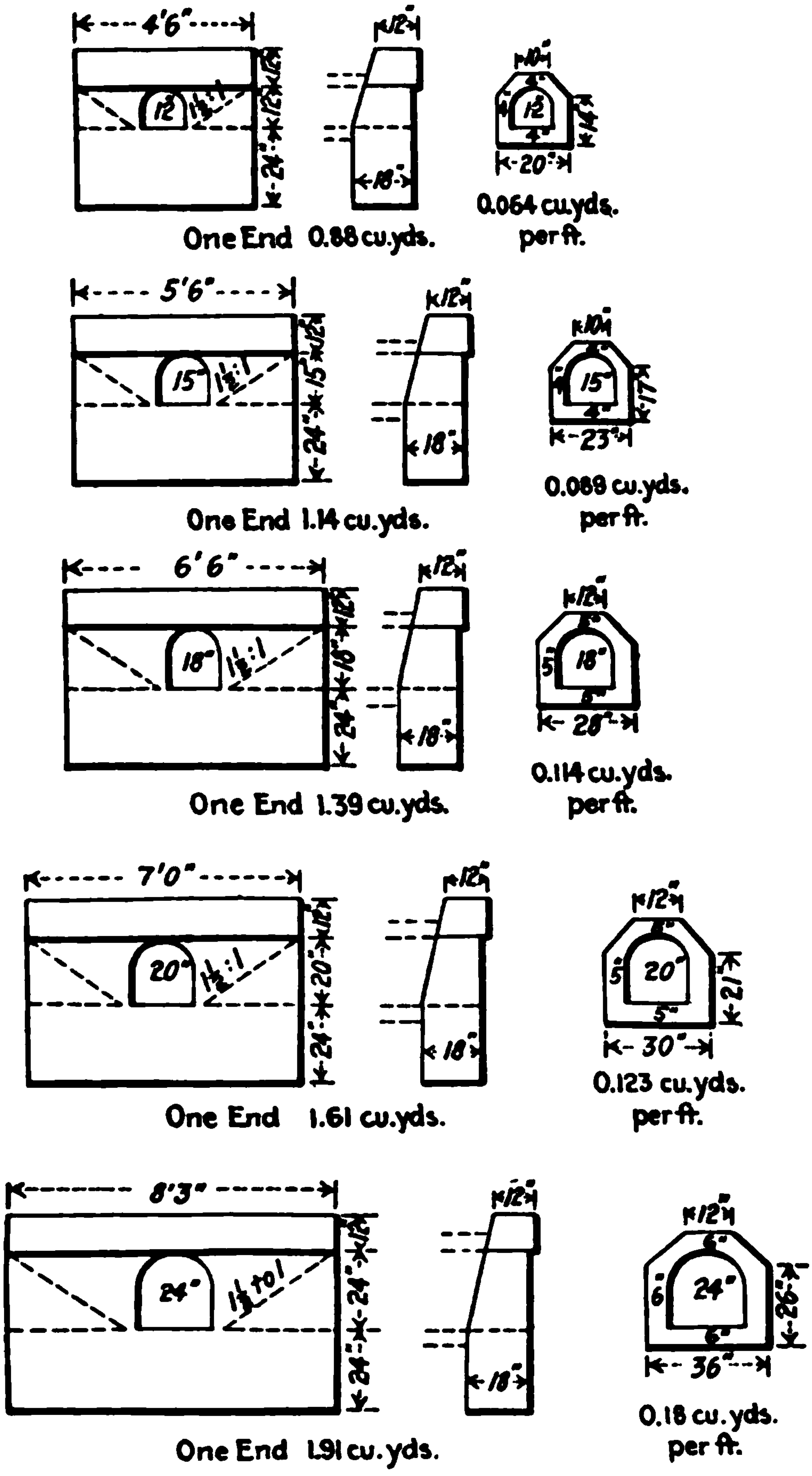
PLATE 6



Span	Thickness of Slab	Thickness of Abutment	Mesh Reinforcement lbs. per sq. ft.
2'0"	6"	12"	0.6
3'0"	6"	12"	1.2
4'0"	6"	12"	1.2
5'0"	8"	12"	1.2

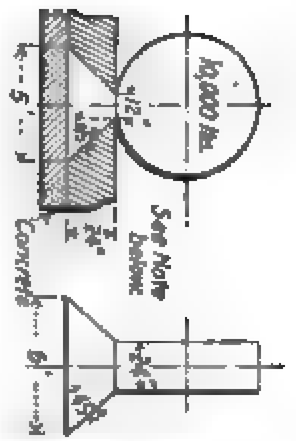
New York State Small Box Culverts

TE 6 A. — Massachusetts Standard for Concrete Arch Culverts

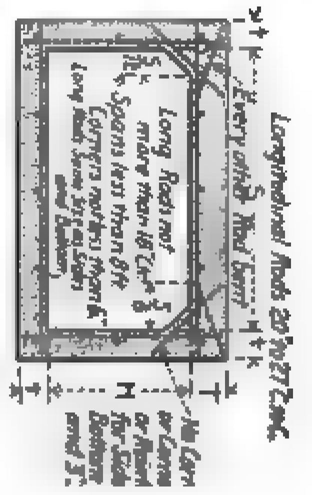


the least excavation and where the water is caught as it flows
f the hill.
ne engineers place the drain in position No. 2 (figure 14), but
equires more excavation for the same depth, and, in the writer's
on, it is more likely to be broken.
e usual *depth for drains* is three feet below the surface.
ere the road is on a descending grade, the water will flow out of

PLATE 6 B



Assumption for Live Load.



Cross Section of Culvert.

TABLE FOR STANDARD CULVERTS. Loading 15-Ton Road Roller, 10,000 lbs. on each wheel. Unit stresses 16,000 lbs. for Steel, 600 lbs. for Concrete, 0.7% of Steel. Los Angeles Co. Highway Com., A. E. Loder, Chief Eng.

D	H	T	t	Top Reinforcement Size	Top Spc.	Top Lgth.	Corner Reinforcement Size	Corner Spc.	Corner Lgth.	Side Walls Reinforcement Size	Side Walls Spc.	Side Walls Lgth.	Bottom Reinforcement Size	Bottom Spc.	Bottom Lgth.	Quan. per lineal ft. box C. Yds. Con.	Quan. per lineal ft. box Steel lb.	
8"	1'	4"	4"	[illegible]	8"	2'-6"										.091	3.70	2'-Span
8"	2'	4"	4"	[illegible]	8"	2'-6"										.115	3.70	
8"	1'	5½"	5"	[illegible]	5"	3'-0"										.155	7.17	3'-Span
8"	2'	5½"	5"	[illegible]	5"	3'-0"										.186	7.17	
8"	3'	5½"	5"	[illegible]	5"	3'-0"										.216	8.12	
8"	1'	6"	5"	[illegible]	8"	4'-8"	[illegible]	16"	1'-6"	[illegible]	16"	1'-9"	[illegible]	16"	4'-8"	.204	12.83	4'-Span
8"	2'	6"	5"	[illegible]	8"	4'-8"	[illegible]	16"	1'-6"	[illegible]	16"	2'-9"	[illegible]	16"	4'-8"	.235	13.55	
8"	3'	6"	5"	[illegible]	8"	4'-8"	[illegible]	16"	1'-6"	[illegible]	16"	3'-0"	[illegible]	16"	4'-8"	.266	15.72	
8"	2'	6½"	5"	[illegible]	7"	5'-8"	[illegible]	14"	1'-6"	[illegible]	14"	2'-9"	[illegible]	14"	5'-8"	.278	17.91	5'-Span
8"	3'	6½"	5"	[illegible]	7"	5'-8"	[illegible]	14"	1'-6"	[illegible]	14"	3'-9"	[illegible]	14"	5'-8"	.309	19.68	
8"	4'	6½"	5"	[illegible]	7"	5'-8"	[illegible]	14"	1'-6"	[illegible]	14"	4'-9"	[illegible]	14"	5'-8"	.339	20.40	
8"	2'	7½"	6"	[illegible]	6"	6'-10"	[illegible]	12"	1'-9"	[illegible]	12"	3'-0"	[illegible]	12"	6'-10"	.373	23.23	6'-Span
8"	3'	7½"	6"	[illegible]	6"	6'-10"	[illegible]	12"	1'-9"	[illegible]	12"	4'-0"	[illegible]	12"	6'-10"	.410	25.14	
8"	4'	7½"	6"	[illegible]	6"	6'-10"	[illegible]	12"	1'-9"	[illegible]	12"	5'-0"	[illegible]	12"	6'-10"	.448	26.10	
8"	2'	8½"	6"	[illegible]	8"	8'-10"	[illegible]	16"	2'-0"	[illegible]	16"	3'-2"	[illegible]	16"	8'-10"	.404	38.32	8'-Span
8"	3'	8½"	6"	[illegible]	8"	8'-10"	[illegible]	16"	2'-0"	[illegible]	16"	4'-2"	[illegible]	16"	8'-10"	.531	41.30	
8"	4'	8½"	7"	[illegible]	8"	9'-0"	[illegible]	16"	2'-0"	[illegible]	16"	5'-2"	[illegible]	16"	9'-0"	.628	43.02	
8"	5'	8½"	7"	[illegible]	8"	9'-0"	[illegible]	16"	2'-0"	[illegible]	16"	6'-2"	[illegible]	16"	9'-0"	.671	46.00	
8"	2'	10"	7"	[illegible]	6½"	11'-0"	[illegible]	13"	2'-6"	[illegible]	13"	3'-3"	[illegible]	13"	11'-0"	.700	54.90	10'-Span
8"	3'	10"	7"	[illegible]	6½"	11'-0"	[illegible]	13"	2'-6"	[illegible]	13"	4'-3"	[illegible]	13"	11'-0"	.742	58.17	
8"	4'	10"	7"	[illegible]	6½"	11'-0"	[illegible]	13"	2'-6"	[illegible]	13"	5'-3"	[illegible]	13"	11'-0"	.786	59.74	
8"	5'	10"	8"	[illegible]	6½"	11'-2"	[illegible]	13"	2'-8"	[illegible]	13"	6'-4"	[illegible]	13"	11'-2"	.900	63.90	
8"	6'	10"	8"	[illegible]	6½"	11'-2"	[illegible]	13"	2'-8"	[illegible]	13"	7'-4"	[illegible]	13"	11'-2"	.949	65.47	
8"	7'	10"	8"	[illegible]	6½"	11'-2"	[illegible]	13"	2'-8"	[illegible]	13"	8'-4"	[illegible]	13"	11'-2"	1.000	68.74	
8"	8'	10"	8"	[illegible]	6½"	11'-2"	[illegible]	13"	2'-8"	[illegible]	13"	9'-4"	[illegible]	13"	11'-2"	1.048	70.31	
8"	2'	11"	8"	[illegible]	6"	13'-2"	[illegible]	12"	3'-0"	[illegible]	12"	3'-7"	[illegible]	12"	13'-2"	.916	69.31	12'-Span
8"	3'	11"	8"	[illegible]	6"	13'-2"	[illegible]	12"	3'-0"	[illegible]	12"	4'-7"	[illegible]	12"	13'-2"	.965	72.71	
8"	4'	11"	8"	[illegible]	6"	13'-2"	[illegible]	12"	3'-0"	[illegible]	12"	5'-7"	[illegible]	12"	13'-2"	1.014	74.41	
8"	5'	11"	8"	[illegible]	6"	13'-2"	[illegible]	12"	3'-0"	[illegible]	12"	6'-7"	[illegible]	12"	13'-2"	1.063	77.81	
8"	6'	11"	9"	[illegible]	6"	13'-4"	[illegible]	12"	3'-0"	[illegible]	12"	7'-6"	[illegible]	12"	13'-4"	1.205	79.94	
8"	7'	11"	9"	[illegible]	6"	13'-4"	[illegible]	12"	3'-0"	[illegible]	12"	8'-6"	[illegible]	12"	13'-4"	1.261	85.34	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6"	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

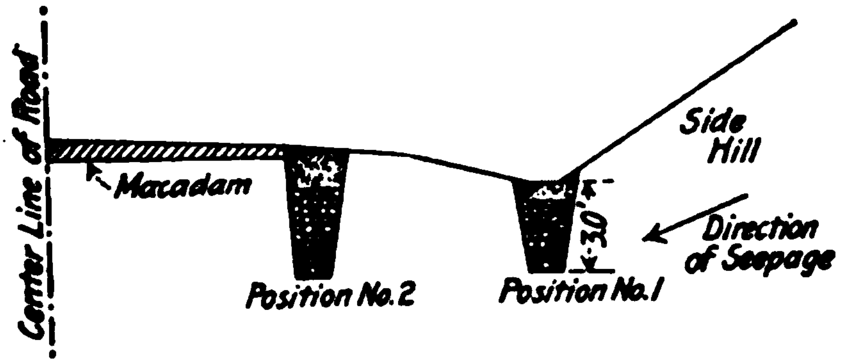


FIG. 14

the hill directly under the stone and the drain is placed as in figure 15, position 1, or two drains are built in position 2. Position 1 is the usual practice, being cheaper and more effective.

The argument for the two side drains is, that in case the throat becomes clogged, a side drain can be taken up without disturbing the macadam. This rarely occurs in a center drain, as it is better protected than those in position 2 and in case the center drain does clog, side drains can be constructed at any time.

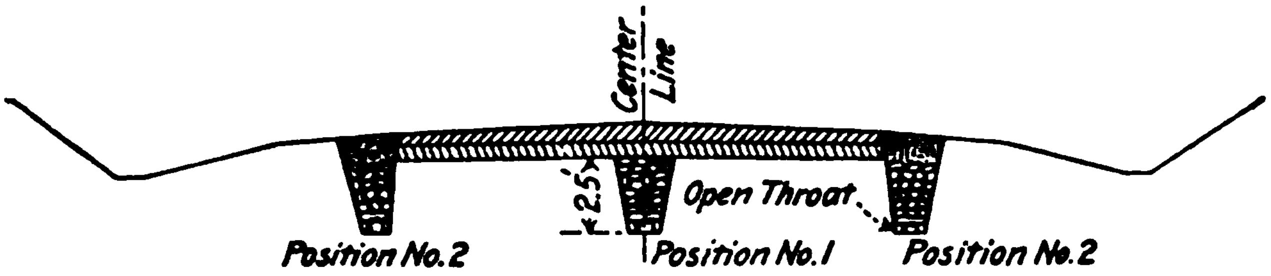


FIG. 15

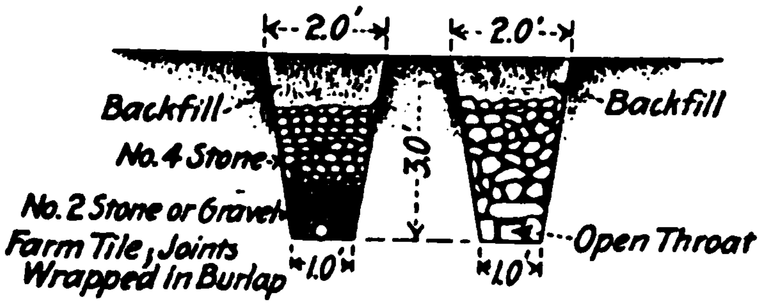


FIG. 16

There are two kinds of drain in general use:

No. 1 is built entirely of stone with an open throat roughly laid as shown; it is satisfactory in a water-bearing strata of gravelly loam or clay, but does not work so well in quicksand, which is liable to fill it up. It is generally cheaper, however, than No. 2.

No. 2 is built of porous farm tile or vitrified tile of a suitable size (usually 3″ to 6″) with open joints, wrapped with a double or triple layer of burlap; the pipe is surrounded and covered with clean gravel or ¾″ crushed stone to a depth of 6″, the remaining depth of the trench being filled with large stone. If this drain has a good fall and the outlet is kept free, it will rarely clog even in bad quicksand.

The author has successfully used the following method to prevent

the outlet from clogging· after being brought out from unde macadam, the drain is continued under and across the ditch then keeping outside the ditch line, and using a slightly sn

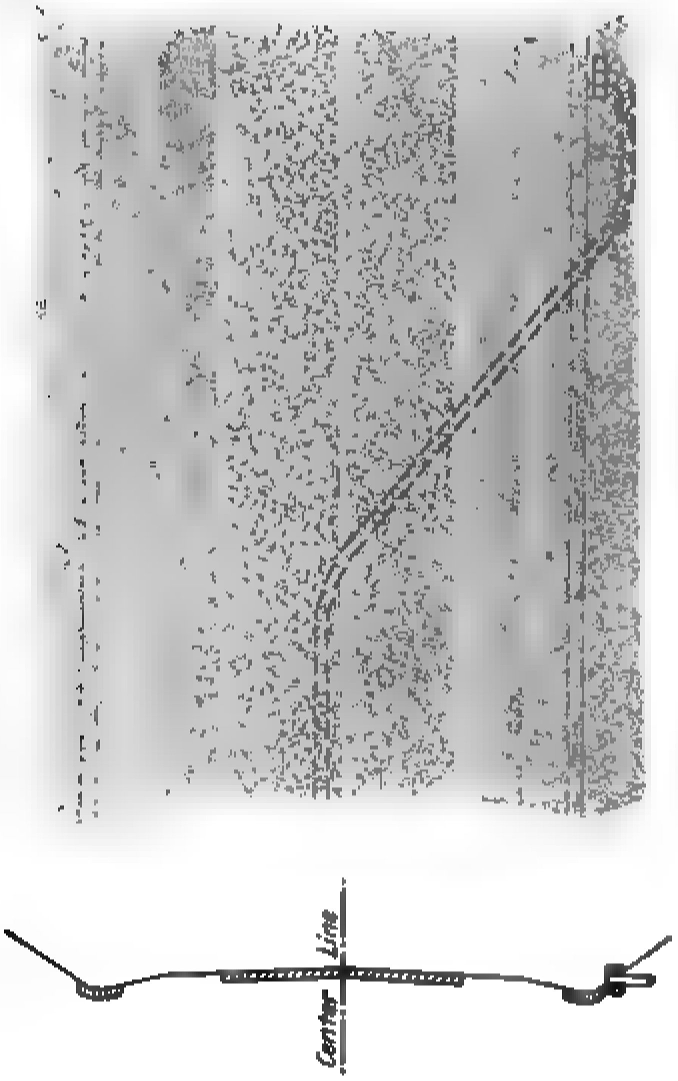


FIG 17

gradient than that of the open ditch, the tile is continued dowr hill until it reaches a point eight or nine inches above the ditch g Here it is turned into the open ditch through a small concrete l wall and what little material it tends to deposit is washed dowr ditch by the surface water. (See figure 17.)

In planning the drainage for a road improvement, it is well to r as few changes as possible from the existing scheme. New cul or a change of direction and amount of water discharged thr farm land is almost certain to result in some friction with the ov of the properties affected.

AMERICAN WATER-WORKS ASSOCIATION

Nominal Inside Diameter Inches	LIGHT 100 Foot Head			MEDIUM 200 Foot Head			HEAVY 300 Foot Head			EXTRA HEAVY 400 Foot Head		
	43 Pounds Pressure			86 Pounds Pressure			130 Pounds Pressure			173 Pounds Pressure		
	Thickness	Weight per Foot	Weight per Length	Thickness	Weight per Foot	Weight per Length	Thickness	Weight per Foot	Weight per Length	Thickness	Weight per Foot	Weight per Length
3	.39	14.5	175	.42	16.2	194	.45	17.1	205	.48	18.0	216
4	.42	20.0	240	.45	21.7	260	.48	23.3	280	.52	25.0	300
6	.44	30.8	370	.48	33.3	400	.51	35.8	430	.55	38.3	460
8	.46	42.9	515	.51	47.5	570	.56	52.1	625	.60	55.8	670
10	.50	57.1	685	.57	63.8	765	.62	70.8	850	.68	76.7	920
12	.54	72.5	870	.62	82.1	985	.68	91.7	1,100	.75	100.0	1,200
14	.57	89.6	1,075	.66	102.5	1,230	.74	116.7	1,400	.82	129.2	1,550
16	.60	108.3	1,300	.70	125.0	1,500	.80	143.8	1,725	.89	158.3	1,900
18	.64	129.2	1,550	.75	150.0	1,800	.87	175.0	2,100	.96	191.7	2,300
20	.67	150.0	1,800	.80	175.0	2,100	.92	208.3	2,500	1.03	229.2	2,750
24	.76	204.2	2,450	.89	233.3	2,800	1.04	279.2	3,350	1.16	306.7	3,680
30	.88	291.7	3,500	1.03	333.3	4,000	1.20	400.0	4,800	1.37	450.0	5,400
36	.99	391.7	4,700	1.15	454.2	5,450	1.36	545.8	6,550	1.58	625.0	7,500
42	1.10	512.5	6,150	1.28	591.7	7,100	1.54	716.7	8,600	1.78	825.0	9,900
48	1.26	666.7	8,000	1.42	750.0	9,000	1.71	908.3	10,900	1.96	1,050.0	12,600

TABLE 15. WEIGHTS OF EXPANDED METAL

TRADE CATALOGUE WEIGHTS

Gauge	Size Mesh	Weight in Pounds per Sq. Ft.
10	3½" × 7"	0.68
12	3½" × 7"	0.54
10	2½" × 5"	0.86
12	2½" × 5"	0.68
14	2½" × 5"	0.48
16	2½" × 5"	0.37
16	1½" × 3"	0.40
16	1" × 2"	0.50
15	1" × 2"	0.57
14	1" × 2"	0.64
13	1" × 2"	0.78

Mesh	Gauge (Stubs)	Strand Standard or Extra	Section Area per Foot of Width	Weight per Sq Ft	Size of Standard Sheets	No of Sheets in Bundle	No. of Sq. Ft in 8' Bundle
¼"	No. 18	Standard	0.209	.74	3' or 6' × 8'	5	120
½"	13	"	0.225	.80	6' × 8' or 12'	5	240
1½"	12	"	0.307	.70	4' × 8' or 12'	5	160
2"	12	"	0.166	.56	5' × 8' or 12'	5	200
3"	16	"	0.083	.28	6' × 8' or 12'	10	480
3"	10	Light	0.148	.50	6' × 8' or 12'	5	240
3"	10	Standard	0.178	.60	6' × 8' or 12'	5	240
3"	10	Heavy	0.267	.90	4' × 8' or 12'	5	160
3"	10	Ex "	0.356	1.20	6' × 8' or 12'	3	144
3"	6	Standard	0.400	1.38	5' × 8' or 12'	3	120
3"	6	Heavy	0.600	2.07	5' × 8' or 12'	3	120
4"	16	Old Style	0.091	.22	4½' × 8' or 9'	6	216

WEIGHT AND SECTIONAL AREA TAKEN FROM I. C. S. HANDBOOK

U. S. Standard Gauge	Size Mesh	Sectional Area in Sq. In. per Foot of Width	Weight in Pounds per Sq. Ft.
18	¾" × 1½"	0.203	0.69
12	¾" × 2"	0.253	0.86
12	1½" × 3"	0.188	0.64
16	2¼" × 6"	0.087	0.29
16	3" × 8"	0.130	0.44
16	3" × 8"	0.059	0.20
12	3" × 8"	0.109	0.37
10	3" × 8"	0.162	0.55
10	3" × 8"	0.243	0.81
10	3" × 8"	0.324	1.07
7	3" × 8"	0.400	1.36
4	6" × 12"	0.245	0.84
4	6" × 12"	0.368	1.26

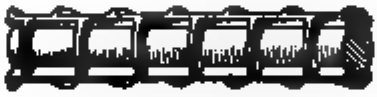
NOTE. — Expanded metal for small culverts is generally specified as weighing a certain number of pounds per square foot and having a mesh approximately the size shown on the plans.

Table 16. Table of Round and Square Bar Weights

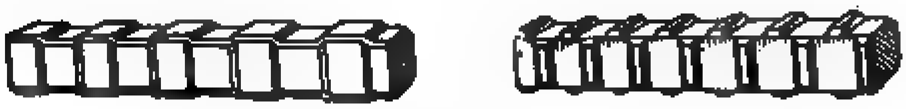
Round Bars			Plain Square Bars and Twisted Square Bars		
Diameter	Area	Weight	Dimension	Area	Weight
$\frac{1}{4}$	.0491	.167	$\frac{1}{4}$	.0625	.212
$\frac{5}{16}$	.0767	.261	$\frac{5}{16}$	.0977	.332
$\frac{3}{8}$	.1104	.376	$\frac{3}{8}$	.1406	.478
$\frac{7}{16}$	.1503	.511	$\frac{7}{16}$	.1914	.651
$\frac{1}{2}$	.1963	.668	$\frac{1}{2}$	.2500	.850
$\frac{9}{16}$	.2485	.845	$\frac{9}{16}$	.3164	1.076
$\frac{5}{8}$	.3068	1.043	$\frac{5}{8}$	3906	1.328
$\frac{11}{16}$	.3712	1 262	$\frac{11}{16}$	.4727	1.607
$\frac{3}{4}$	.4418	1 502	$\frac{3}{4}$	.5625	1.913
$\frac{13}{16}$	.5185	1.763	$\frac{13}{16}$	.6602	2.245
$\frac{7}{8}$	.6013	2.044	$\frac{7}{8}$	.7656	2.603
$\frac{15}{16}$	.6903	2 347	$\frac{15}{16}$	.8789	2.988
1	.7854	2.670	1	1.0000	3.400
$1\frac{1}{8}$	.9940	3.380	$1\frac{1}{8}$	1 2656	4.303
$1\frac{1}{4}$	1.2272	4.172	$1\frac{1}{4}$	1.5625	5.313
$1\frac{3}{8}$	1.4849	5.049	$1\frac{3}{8}$	1 8906	6.428
$1\frac{1}{2}$	1.7671	6.008	$1\frac{1}{2}$	2.2500	7.650

Diameters expressed in inches. Areas expressed in square inches.
Weights expressed in pounds per foot of length.
The twisted square bar is known as the Ransome Bar.

Ransome Bar.



Kahn Cup Bar.



Corrugated Bars.

Diamond Bar.

Thacher Bar.

TABLE 16. *Continued*

Nominal Size of Bar	Weight and Net Sectional Areas of Different Reinforcing Bars									
	Kahn Cup Bar		Twisted Lug Bar		Corrugated Bars		Thacher Bar		Diamond Bar	
	Area	Weight	Area	Weight	Area	Weight	Area	Weight	Area	Weight
[illegible]			0.0625	0.222			0.047	0.16	0.062	0.22
[illegible]	0.1406	0.502	0.1406	0.492			0.100	0.34	0.141	0.48
[illegible]	0.2500	0.893	0.2500	0.870	0.25	0.86	0.18	0.61	0.250	0.85
[illegible]	0.3906	1.394	0.3906	1.350			0.28	0.95	0.391	1.33
[illegible]	0.5625	2.008	0.5625	1.940	0.56	1.93	0.41	1.39	0.563	1.91
[illegible]	0.7656	2.733	0.7656	2.640	0.77	2.65	0.55	1.87	0.766	2.60
1	1.0000	3.570	1.0000	3.450	1.00	3.45	0.71	2.41	1.000	3.40
1 [illegible]	1.2656	4.518	1.2656	4.350			0.90	3.06		
1 [illegible]	1.5625	5.578	1.5625	5.370	1.56	5.36	1.10	3.74	1.563	5.31

Length Feet	CONCRETE CULVERTS — Size of Opening [1]										CAST IRON PIPE CULVERTS						Length Feet
	2′×1.5′	2′×2′	3′×2′	3′×3′	4′×2′	4′×3′	4′×4′	5′×3′	5′×4′	5′×5′	12″ Pipe	14″ Pipe	16″ Pipe	18″ Pipe	20″ Pipe	24″ Pipe	
20	$63	$76	$79	$97	$90	$107	$127	$127	$147	$170							20
22	68	81	86	104	97	115	136	137	158	181							22
24	72	86	92	111	104	124	145	146	169	193	$44	$51	$ 61	$ 72	$ 83	$107	24
26	77	91	99	118	111	132	154	156	179	204							26
28	81	96	105	126	118	140	163	166	190	216							28
30	86	101	111	133	126	148	172	175	200	227	51	63	74	88	101	131	30
32	91	106	118	140	133	156	181	185	211	238							32
34	95	111	124	148	140	164	190	194	221	250							34
36	100	118	131	155	147	172	199	204	232	261	61	74	87	104	119	156	36
38	104	121	137	162	154	180	208	214	242	273							38
40	109	126	143	169	162	188	217	223	253	284							40
42	114	131	150	177	169	196	226	233	263	295	60	84	100	120	137	180	42
44	118	136	156	184	176	205	235	243	274	307							44
46	123	141	163	191	183	213	244	253	284	318							46
48	127	146	169	199	190	221	253	262	295	330	78	95	114	135	156	205	48
50	132	151	175	206	198	229	262	272	305	341							50
Cost per ft	$2.30	$2.50	$3.20	$3.63	$3.60	$4.06	$4.50	$4.83	$5.27	$5.70	$1.45	$1.80	$2.18	$2.62	$3.06	$4.07	

Note: — These approximate costs figured on a basis of $8.00 per cu. yd. for Concrete Decks and Parapets; $6.00 per cu. yd. for Concrete Bottoms, sides, and wings; 10 cts. per sq. ft. for Expanded Metal in place. Medium weight Cast-Iron Pipe figured at $35.00 per ton in place. $9.00 per cu. yd. for Headwalls. See page 300 for quantities of 2d and 3d cl concrete.

[1] Span is noted 1st, that is a 3′ × 2′ Culvert means Span 3′ Height 2′.

TABLE 18. PROPERTIES OF CAMBRIA STANDARD I-BEAMS

Depth of Beam	Weight per Foot	Area of Section	Thickness of Web	Width of Flange	For Fiber Stress of 12,500 lbs. per Sq. In. for Bridges
Inches	Pounds	Sq. Inches	Inch	Inches	Coefficient of Strength
3	5.50	1.63	.17	2.33	13,790
3	6.50	1.91	.26	2.42	14,950
3	7.50	2.21	.36	2.52	16,180
4	7.50	2.21	.19	2.66	24,850
4	8.50	2.50	.26	2.73	26,480
4	9.50	2.79	.34	2.81	28,110
4	10.50	3.09	.41	2.88	29,750
5	9.75	2.87	.21	3.00	40,300
5	12.25	3.60	.36	3.15	45,390
5	14.75	4.34	.50	3.29	50,490
6	12.25	3.61	.23	3.33	60,520
6	14.75	4.34	.35	3.45	66,610
6	17.25	5.07	.47	3.57	72,740
7	15.00	4.42	.25	3.66	86,260
7	17.50	5.15	.35	3.76	93,290
7	20.00	5.88	.46	3.87	100,430
8	18.00	5.33	.27	4.00	118,490
8	20.25	5.96	.35	4.08	125,400
8	22.75	6.69	.44	4.17	133,570
8	25.25	7.43	.53	4.26	141,740
9	21.00	6.31	.29	4.33	157,260
9	25.00	7.35	.41	4.45	170,260
9	30.00	8.82	.57	4.61	188,640
9	35.00	10.29	.73	4.77	207,020
10	25.00	7.37	.31	4.66	203,500
10	30.00	8.82	.45	4.80	223,630
10	35.00	10.29	.60	4.95	244,050
10	40.00	11.76	.75	5.10	264,480
12	31.50	9.26	.35	5.00	299,740
12	35.00	10.29	.44	5.09	317,030
12	40.00	11.76	.56	5.21	341,540

TABLE 18. *Continued*

Depth of Beam	Weight per Foot	Area of Section	Thickness of Web	Width of Flange	For Fiber Stress of 12,500 lbs. per Sq. In. for Bridges
Inches	Pounds	Sq. Inches	Inch	Inches	Coefficient of Strength
15	42.00	12.48	.41	5.50	490,840
15	45.00	13.24	.46	5.55	506,490
15	50.00	14.71	.56	5.65	537,130
15	55.00	16.18	.66	5.75	567,770
15	60.00	17.65	.75	5.84	598,410
18	55.00	15.93	.46	6.00	736,620
18	60.00	17.65	.56	6.10	779,440
18	65.00	19.12	.64	6.18	816,200
18	70.00	20.59	.72	6.26	852,970
20	65.00	19.08	.50	6.25	974,600
20	70.00	20.59	.58	6.33	1,016,490
20	75.00	22.06	.65	6.40	1,057,340
24	80.00	23.32	.50	7.00	1,449,460
24	85.00	25.00	.57	7.07	1,505,430
24	90.00	26.47	.63	7.13	1,554,450
24	95.00	27.94	.69	7.19	1,603,470
24	100.00	29.41	.75	7.25	1,652,490

Explanation of the coefficient of strength in the above table and xamples showing use in practice.

The coefficient of strength for each sized beam represents the naximum uniformly distributed load, in pounds, that will produce a iber stress not exceeding 12,500 lbs. per sq. inch multiplied by the pan in feet.

If the load to be investigated is a concentrated load it must be hanged to an equivalent uniform load in order to use the values given. This is done by multiplying the concentrated load by 2.

EXAMPLE: Suppose that it is required to determine the size I-beam hat will carry a 40,000 lb. load in the center of a 15′ span and a uniformly distributed load of 20,000 lbs. The coefficient of resistance or the concentrated load will be 2 (40,000) × 15 = 1200000

Uniform load 20,000 × 15 = 300000

1500000

The required beam must have a coefficient of resistance of 1500000 plus the coefficient due to its own weight. A 24″ beam weighing 90 lbs. per foot has a coefficient of 1,554,450.

The beam weighs 90 × 15 = 1,350. The coefficient for the beam weight is 1,350 × 15 = 20,250, which deducted from 1,554,450 gives a coefficient of 1,534,200, which is slightly greater than required and is safe.

CHAPTER IV

FOUNDATIONS FOR BROKEN STONE ROADS

CONCRETE foundations are considered under Brick Pavements in chapter V.

The real foundation of a road is the earth subgrade; generally, however, the term foundation is used in speaking of the lower course of stone, gravel, etc., used to distribute the concentrated wheel loads. A discussion can be developed under the following heads:

1. The bearing power of different soils.
2. The concentrated wheel loads on improved roads.
3. The distributing action of foundation courses and the depth required for different soils.
4. The different kinds of foundation courses.
5. The distribution of the stone in the foundations.
6. Special cases.

1. Bearing Power of Soils

The subgrade develops its greatest bearing power when dry. In the following discussion we assume that the soils are protected by a well-designed drainage system.

Mr. W. E. McClintock, Mem. Amer. Soc. C. E., Chairman of the Massachusetts Highway Commission, published in the 1901 report of that Commission a valuable statement of the results of their investigations on the bearing power of soils and the distribution of wheel loads by the macadam. The conclusions have been well tested in practice and found to be satisfactory.

"The Commission has estimated that non-porous soils drained of ground water, at their worst will support a load of about 4 lb. per square inch; and having in mind these figures the thickness of broken stone has been adjusted to the traffic.

"On a road built of fragments of broken stone the downward pressure takes a line at an angle of 45 degrees from the horizontal and is distributed over an area equal to the square of twice the depth of the broken stone. If a division of the load in pounds at any one point by the square of twice the depth of the stone in inches gives a quotient of four or less, then will the road foundation be safe at all seasons of the year. On sand or gravel the pressure can be safely put at twenty pounds per square inch. . . .

"Acting on this theory the thickness of the stone varies from four inches to sixteen inches, the lesser thickness being placed over good gravel or sand, the greater over heavy clay, and varying thicknesses on other soils. In cases where the surfacing of broken stone exceeds six inches in thickness, the excess in the base may be broken stone, *stony gravel or ledge* stone; the material used for the excess *depending entirely upon the cost*, either being equally effective."

2. Concentrated Wheel Loads

There should be some limit placed by law to the maximum load per lineal inch of tire for vehicles using improved roads. The roads can then be designed for this load with no danger of failure from unreasonable pressures. Road work is handicapped in this country by the lack of wide tire statutes and the regulation of traction engines using sharp lugs on the wheels. At present it is necessary to assume a loading that will probably not be exceeded by the unregulated traffic. Many engineers favor a law limiting the load on improved roads to 700 to 800 lb., per lineal inch, which is a reasonable limit; with a six inch tread this would mean a load of nine tons for a four wheel truck provided the load was uniformly distributed. This is beyond the limits of team hauling.

Most of the mechanical trucks in present use have tires wide enough to reduce the pressure below this limit. Near some of the large cities, however, mechanical trucking has increased to proportions that amount to a regular freight line and excessive loads are carried; the load and speed for such trucks must be regulated, for no road can stand abuses of this character.

Heavily loaded farm wagons exert a pressure of about 350 lb., per lineal inch of tire width as determined from the records of produce dealers in Western New York, and the author believes that a road designed to distribute a 4,200-pound wheel load on a six-inch tire would be safe.

NOTE:—The length of wheel bearing on a well-constructed macadam road is about 1".

The use of this loading and the application of the rules for distribution of pressure given by Mr. McClintock in the preceding quotation results in a depth of 15" for heavy clay or a fine sandy loam, and a depth of 5" for gravel, which check his results.

The thickness to be used in the intermediate cases must depend on the judgment of the engineer. The following examples are intended only as a guide for the more common cases. The amount for special cases often depends on trial.

Sand and gravel require from 4" to 6" total thickness; New York State uses 6" as a minimum; Massachusetts uses the following section on good gravel:

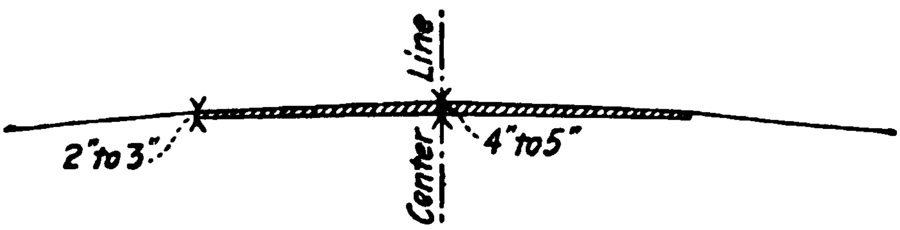


FIG. 18

Wherever the total depth is less than 5", the stone should be laid in one course and classified as top stone.

For ordinary clay loam an average depth of 6" to 8" is sufficient in cut; for fills over 2' deep, 6" is enough; high fills even of clay, *after they have once* settled, rarely give trouble with 6" of metaling.

Heavy clay requires at least 12″ in cut; if the soil is springy and especially hard to drain, 15″ to 18″ is advisable.

For shallow fills (see figure 19):

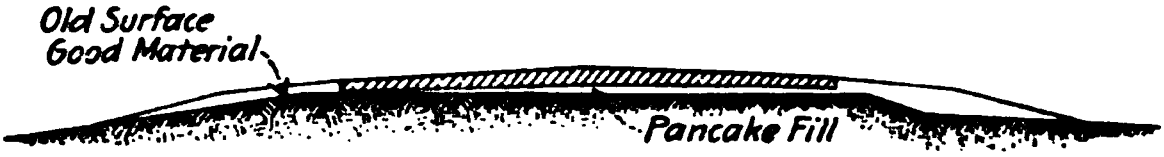


FIG. 19

In shallow or "pancake" fills, clay or fine sandy loam should never be used where the natural surface at this point is of a better variety, as they are almost certain to become saturated with water and will either squeeze or heave out of shape; long, shallow fills are to be avoided, which is considered in placing the grade line, but where unavoidable, the best available material should be obtained and the original surface well broken up to form a bond with the new fill. Where clay is used, it should be treated as in cut. For fills of intermediate depths [1′ to 2′] 8″ to 9″ is satisfactory.

A fine sandy loam is difficult to drain because of its strong capillary action. Mr. Charles Mills, Chief Engineer of the Massachusetts Highway Commission, in the report for the year 1902 states that a loam of which 30% or more will pass a 100 sieve will require from 10″ to 15″ of stone.

To illustrate the different stone depths that may be used in a short distance, an extract follows from the construction report on foundations for "Clover Street, Section 1," a road near Rochester, N.Y. This was built in 1907–1908 and has held satisfactorily under farm traffic.

CLOVER STREET ROAD, SECTION 1

The normal depth of stone on this road was 7″ { 3″ Top, 4″ Bottom }

Station to Station		Character of Subgrade	Total Depth of Stone
180	183 + 25	Cut in sand and gravel	6″
183 + 25	186 + 25	Clay fill	8″
186 + 25	187	Clay cut	11″
187	190	Sand, gravel and clay	7″
190	191	Clay cut	12″
191	193	Clay loam fill	7″
193	200	Sand and gravel	6″

PREPARATION OF SUBGRADE

It is evident from the pressures to which a road is subjected that *the subgrade must be* well consolidated before placing the foundation

stone. This is usually effected by rolling with a 10 or 15 ton steam roller, exerting a pressure of 350 to 500 pounds per linear inch of wheel width, and is continued until the grade is firm and compact.

The difficulties of consolidation in different soils and the methods of overcoming them will be included in chapter XI.

KINDS OF FOUNDATION COURSES

The foundation courses in ordinary use are as follows:

1. Crushed stone
2. Screened gravel
3. Field stone sub-base
4. Pit gravel sub-base
5. Field stone sub-base bottom course
6. Pit gravel sub-base bottom course
7. Quarry stone base or Telford

1. Broken Stone Bottom Course.

This style of construction is the one in most general use. Where local stone is abundant and well distributed, such a course will cost from $2.00 to $2.50 per cubic yard rolled in place; where imported stone is necessary, the cost depends largely upon the freight rate and the length of haul and may run as high as $5.00. Bottom of this kind is generally used where the total depth of stone metaling does not exceed 6″ to 8″ after rolling. Beyond these depths it is often cheaper to substitute sub-base or sub-base bottom course for a part or the whole of the broken stone course.

The method of construction by the New York State Highway Commission is shown in the following extract from their 1911 specifications:

Stone Macadam Bottom Course

"After the subgrade has been prepared and has been accepted by the Engineer, a layer of broken stone of the approved size and quality for bottom course shall be spread evenly over it to such a depth that it shall have, when rolled, the required thickness. The depth of the loose stone shall be gauged by laying upon the subgrade cubical blocks of wood of the proper size and spreading the stone evenly to conform to them."

"The roller shall be run along the edge of the stone backward and forward several times on each side before rolling the center. Before putting on the filler the course shall be rolled until the stone does not creep or weave ahead of the roller. In no case shall the screenings or sand for filler be dumped in mass upon the crushed stone, but they shall be spread uniformly over the surface from wagons or from piles that have been placed on the shoulders. It shall then be swept in with rattan or steel brooms and rolled dry. This process shall be continued until no more will go in dry, when the surface shall, if required *by the Engineer*, be sprinkled to more effectually fill the *voids. No filler shall be left* on the surface, and surface of bottom

course stone shall be swept clean before covering with top course. Only such teaming as is necessary for distributing the materials will be allowed on the bottom course. Any irregularities or depressions, the result of settlement, rolling or teaming, if slight, shall be made good with broken stone of the same size used in the bottom course, otherwise the stone shall be removed and the subgrade regraded and rolled. Such removal and restoring of the surface shall be made at the expense of the Contractor. Screenings shall not be used in leveling up irregularities or depressions."

Massachusetts uses no filler; otherwise their construction is substantially the same as New York.

Where imported stone is specified or the local stone is suitable for both top and bottom courses, the size used for bottom course is known commercially as "No. 4 stone" and ranges from 2½" to 3½" in its greatest dimension; the smaller sizes are used for the top course, for concrete and for filler; where the local material is only fit for bottom, the course is made up of stone ranging from 1" to 3½" in order to use up the total output of the crusher. The stone smaller than 1" is used for filler, on the shoulders, and sometimes for the cheaper grades of concrete. In specifying the sized stone for a particular job, economy is considered. Stone sized from 1" to 3½" is perfectly satisfactory. The only reason for limiting the usual size from 2½" to 3½" is that it leaves the 1" to 2½" stone for the top course; a uniform grade is important for the top and the size mentioned gives a smooth finish.

The ratio of loose depth to rolled depth is given on page 234.

Where filler is not used in the construction of the bottom course more binder is required for the top; it is our opinion that the use of filler is the better construction.

The clause concerning teaming in the quoted specifications is a dead letter; teaming helps to consolidate the bottom provided it is distributed over the full width and care is taken in watching the course to prevent loss of shape when the traffic is first turned on or after a long continued rainfall.

2. Gravel Bottom Course.

Screened gravel 1" to 3½" in size is used in place of crushed stone; the course is constructed in the same manner as described above, except that a filler containing some clay or clay loam is preferable to a coarse sand. and it is often necessary to wet the course in order to consolidate it satisfactorily.

The choice between a screened gravel or crushed stone bottom depends entirely on the relative cost. Under favorable conditions a screened gravel bottom course will cost from $1.30 to $2.00 per cubic yard, rolled in place.

3. Field Stone Sub-base.

Field stone sub-base is constructed, as shown in the cut, of field *boulders roughly placed* and filled with gravel, waste No. 2 *stone or stone chips;* no attempt is made to finish the top of the

course exactly to line and grade, as any small inequalities can be filled with bottom stone. The depth varies from 5″ to 12″ depending on the soil encountered and the size of the available field stone. In designing a bottom course of this kind, care must be taken to have accurate data as to the average size of stone available. If the demands of a foundation were fully satisfied by a 5″ sub-base course, it might still be more economical to use a 7″ course if the stone averaged seven inches, because the extra work of sorting and sledging to a 5″ size would result in a higher cost per square yard than for a 7″ depth.

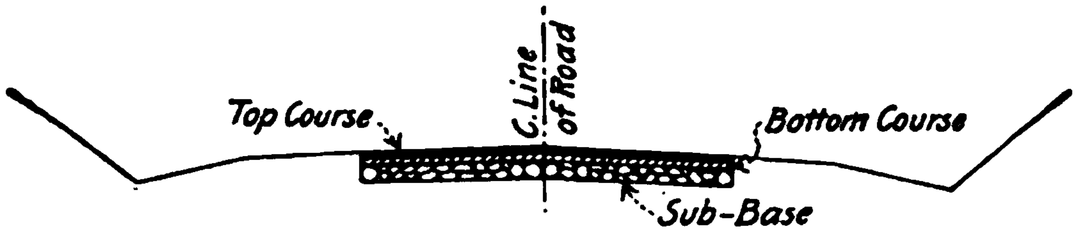


FIG. 20

The amount of stone and filler required per cubic yard in place is given on page 234.

Under favorable conditions this sub-base can be constructed for $1.00 to $1.50 per cubic yard.

4. Pit Gravel or Creek Gravel Sub-base.

Stony gravel is a satisfactory material for sub-base; it can be readily constructed for any depth from 2″ to 24″ if required, and where a pit or creek bar is near, the cost of such a course should run from $0.80 to $1.25 per cubic yd.

The ratio of loose to consolidated gravel for such a course is given on page 234.

5. Field Stone Sub-base Bottom Course.

Sub-base bottom course is essentially the same construction as sub-base, except that, as the top course is placed directly upon it, the stone must be more carefully assorted as to size, more carefully placed as to line and grade, and a better grade of filler must be used.

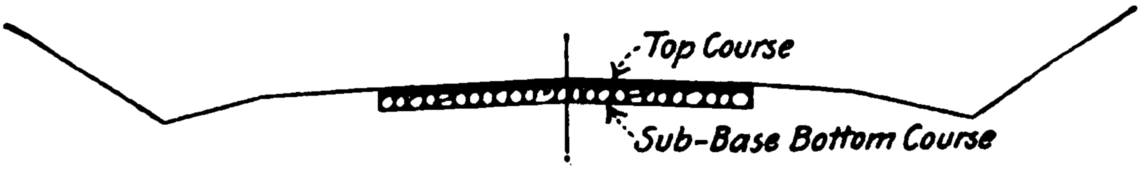


FIG. 21

The course can be of any depth from 5″ up, depending, as for sub-base, on the soil and average size of stone; it is practically impossible to make a large stone bottom of this kind conform exactly to line and grade; a variation of 1″ either above or below grade is usually allowed and the inequalities taken out with the top stone; this requires that the top course must be at least 3″ deep after rolling.

Sub-base bottom is especially applicable for long stretches of road

requiring a depth of 9″ to 12″; it usually costs from $1.30 to $1.70 per cubic yard in place where fence stone is available, and by its use the item of higher-priced bottom stone is reduced. However, on a hard foundation it is generally better to use 3″ to 4″ of ordinary broken stone bottom course instead of the sub-base bottom even if more expensive, because the small stone construction is not as rigid as the boulders and the top course will wear longer.

An extract from the 1911 New York State Specifications is given below:

Sub-base Bottom Course

"After the subgrade has been prepared and has been accepted by the Engineer, a layer of an approved quality of field stone, quarry stone, or clean stone from stream channels shall then be spread upon the subgrade to such a depth that it shall have when thoroughly consolidated the required thickness.

"The stone shall be roughly placed by hand, with the larger stone in the center of the course. It shall then be rolled with a ten-ton roller, after which any projecting, bridged, or loose stones shall be broken by hand. A filler of approved clean gravel, stone chips, or crushed stone of sufficient quantity to completely fill all voids and depressions shall then be spread, after which the rolling shall continue until the entire course is thoroughly consolidated, and conforms with the typical section shown on the plans.

"When called for on the plans, or ordered by the Engineer, lateral drains of loose stone shall be constructed every 100 feet on each side and staggered, draining into ditches.

"No top course shall be placed on sub-base bottom course until the sub-base bottom course has been accepted by the Engineer.

"The item of sub-base bottom course will include the stone, filler, manipulation, and all necessary work connected therewith."

6. Pit Gravel Sub-base Bottom Course.

A clean stony gravel makes a satisfactory course; the depths vary from 6″ to 15″; pit or creek gravel even when unusually coarse has an excess of fine material; when such gravel is used as a bottom course a top course thickness of at least four inches is advisable. (See discussion by Mr. McClintock, Chairman of the Massachusetts Highway Commission, page 60.)

The cost of gravel sub-base bottom course will range from $0.80 to $1.50 per cubic yard in place, providing hauls are short.

The depth of the gravel is gauged by blocks or lines and the ratio of loose to rolled depth is approximately 1.2 (see page 234).

7. Telford Base.

Telford base is rapidly going out of use in the United States because of the difficulty of maintaining a top course laid upon it. It seems to be too rigid and is more expensive than sub-base or sub-base *bottom course, costing* about $1.80 to $2.00 per cubic yard under *favorable conditions.*

A good description of a telford construction is given by Mr. William Pierson Judson in "Roads and Pavements." The following quotation is an extract from his book:

"On this subgrade are then placed by hand the stones forming the telford foundation, which may vary in size as shown below: each stone must be set vertically upon its broadest edge, lengthwise across the road and forming courses and breaking joints with the next course, so as to form a close and firm pavement. The stones are then bound by inserting and driving stones of proper size and shape to wedge the stones in their proper position. All projecting points are then broken with a sledge or hammer so that no projections shall be within four inches of the finished grade line.

"The telford foundation is then rolled with a steam roller of ten or more tons weight, until all stones are firmly bedded and none move under the roller. All depressions are then filled with stone chips not larger than two and one-half inches, and the whole left true and even and four inches below the line of finished grade and cross-section.

"A good workman will average about twenty minutes in setting a square yard of this telford foundation, which may be formed of any kind of quarried rock which is most available: cobble-stones are not suitable.

"The practice in 1901 in the states named is here shown:"

Table 19. Sizes of Stone for Telford Foundation, in Inches

State	Depth, as set on Edge		Width, as set		Length set across Road		Remarks
	Max.	Min.	Max.	Min	Max	Min	
New Jersey	8	8	4	—	10	—	Alternate end-stones double length.
Mass. .	6	5	[illegible]	4	15	6	Two inches gravel rolled on subgrade as base.
Conn. ...	8	8	10	6	18	8	Macadam covering formed in one layer
New York ..	8	6	10	4	15	6	Used only on unstable ground as foundation for macadam.

Distribution of Stone in Foundations.

In the discussion of sections, Table 9 shows that most of the traffic keeps to the middle ten or twelve feet; to make a consistent design the foundation should therefore be thicker in the middle than on the sides for the ordinary crushed stone bottom, and where subbase is required it is often unnecessary to place it the full width of the metaling.

Figure 22 is an example of such a foundation course for ordinary soils as used *by the New York State Highway Commission in 1910.*

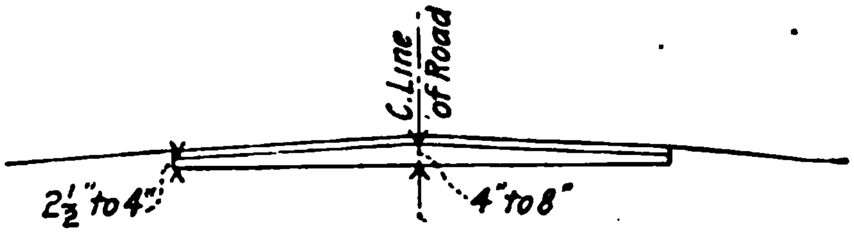


FIG. 22

Figure 23 is an example of an economical sub-base for a light traffic road as used by the Illinois Highway Commission in 1910.

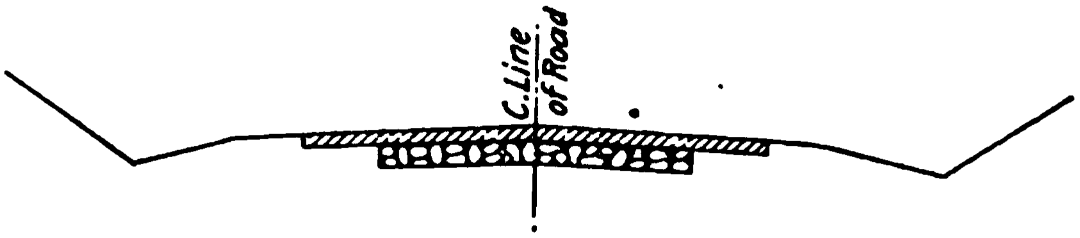


FIG. 23

On a heavy traffic road, however, the writer does not believe that the width of sub-base should be less than the width of metaling.

Special Cases.

Long stretches of comparatively level ledge rock, peat, muck, and vegetable loam may be placed under this head.

Where a road is on the surface of ledge rock for any distance, the usual cross-section of part cut and part fill cannot be used because of the high cost of shallow rock excavation for ditches; the grade should be lifted to make the normal section a fill and the best available material (not clay) used in its construction. Where conditions of this kind prevail, dirt is usually hard to obtain and often a stone fill is cheaper and also more satisfactory.

The construction shown below was used for a stretch of two and one-half miles on the Leroy-Caledonia State Highway in New York, where ledge rock was encountered as described.

The price for the stone fill was $1.23 per cubic yard in place, constructed as shown; the road was built in 1910 and has given satisfaction; such a base, however, is very rigid, which will probably cause a more rapid deterioration of the top course than if earth were used; the minimum thickness of top for such a fill is 3″ as it is impossible to construct it exactly to line and grade; it was found that by allowing a variation of 1″ either above or below the grade elevation, the fill could be readily constructed, and these small inequalities were taken out with the top stone. A top course having such a variable thickness should be paid for by weight and not by volume in place. (See page 230, Cost Data.)

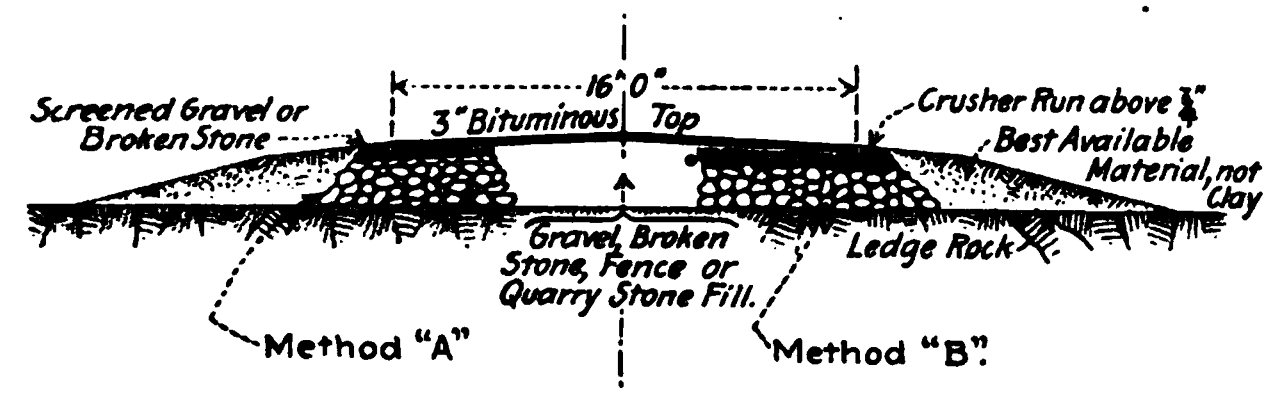


FIG. 24

Fill can be made of fence stone, gravel, quarry spalls, stone chips, or run of crusher stone over $\frac{3}{4}''$ in size.

METHOD A.—Boulders up to 2 cu. ft. can be used, placing the largest in the bottom of the fill; the top layer must be fairly uniform and not over 8" in size and must be roughly placed by hand to reduce the voids as much as possible, provided this layer of large stone is within 4" of the bottom of the top course. The top 8" to be filled with stone chips or gravel and a cushion of at least 2" of screened gravel, stone chips or crusher run of broken stone over $\frac{3}{4}''$ in size to be placed on top to bring the fill to the correct grade and crown for the top course.

METHOD B.—Same materials and manipulation as Method A, except that provided the top of the boulder fill is more than 4" from the bottom of the top course the top layer of the boulder fill need not be placed by hand. (See sketch, Method B.)

Peat, Muck, Vegetable Loam, or Silt.

Where the material is semifluid the only solution is a pile and grillage foundation.

Swamps, as ordinarily encountered, can be treated successfully by using a corduroy or mattress foundation covered with a deep fill of gravel or large stone. In some cases where the muck is comparatively stiff, a gravel or boulder fill alone will give a satisfactory foundation.

Where swamps are crossed by improved roads, the location usually follows the old road which has often been corduroyed in the past; in such a case the old foundation should not be disturbed; a sufficient additional depth of stone can be added to keep the shape of the section intact.

As an example, the Scottsville-Mumford New York State improvement crossed a 1000 ft. stretch of muck on the old road location; it was found that the original cedar corduroy was in good shape; an 18" depth of large boulders was placed on the old foundation and surfaced with 6" of broken stone macadam. This stretch of road has kept its shape and has not settled; it affords a good example of the statement made on page 61, that in many special cases the depth of the stone is determined by trial; the boulders were put on in successive layers of 6" each until there was no material movement under the roller and then surfaced with the broken stone macadam. *Under a heavy load the* whole road-bed will vibrate for 100 feet, *but the shape remains intact.*

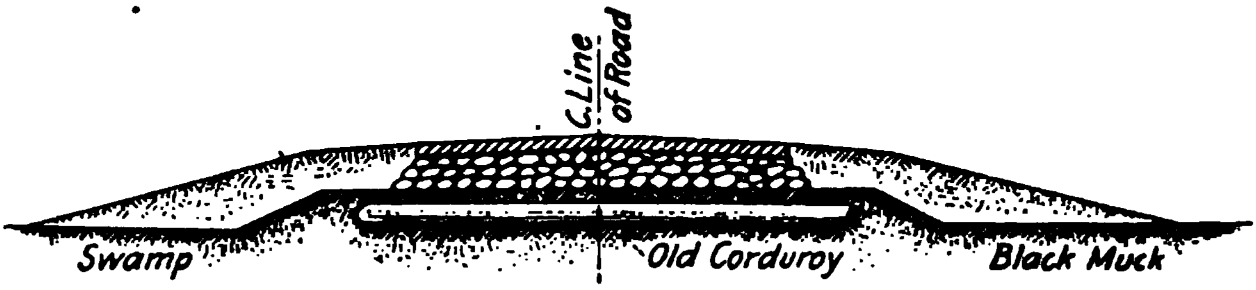


FIG. 25

Conclusions.

In the design of a road, the amount of material required for the foundation courses can be only approximated. This is the only item in the preliminary estimate that cannot be figured within definite limits. It can be closely estimated if careful data on the soils is obtained from local people and from the preliminary survey (see page 124), but a certain leeway must be given the constructing engineer so that he may vary the estimated depths to meet the construction conditions and build a consistent road.

CHAPTER V

TOP COURSES

THE selection of the most economical top course that is suitable for a given road is the hardest problem of Highway Engineering.

The relative economy of the different constructions is theoretically expressed by the sum of the first cost and the capitalized cost of maintenance and renewal. The first can be readily estimated, but the cost of maintenance and renewal cannot be figured with any degree of accuracy for single special cases, and even on large systems it can only be approximated because of the new factor of motor vehicle traffic. The life of any surfacing is comparatively short, a fact generally overlooked in most of the popular literature on Good Roads.

On any road the amount and class of traffic will fluctuate, and roads that are designed for light travel will often fail under temporary heavy traffic which, for some reason, is diverted from its normal course. The first improved roads built in any locality will for a time carry more than their share of the traffic, which is naturally reduced by the subsequent construction of adjacent improvements. It can be readily seen that it is difficult to judge the amount of traffic a road will handle and that a short-time traffic estimate is valueless as a basis for a definite conclusion.

The design of the top course is usually based on a comparison of the actions of different kinds of previously improved roads, that serve districts similar to that under consideration.

Any discussion at this time of the methods of construction of the newer types of surfacing will be of little permanent value, and this chapter is largely confined to crown, thickness, footing, and cost, and to a brief description of the methods and some of the constructional difficulties we have personally encountered. Any conclusions which may be adopted are liable to be modified by further observation of the behavior of the different tops under longer continued service conditions.

Waterbound Macadam

Waterbound macadam is constructed of crushed fragments of suitable rock, filled with rock dust and sprinkled and rolled until firm and hard. The cost varies from about $3.50 per cubic yard where local materials are available to $6.00 where the stone is imported and the haul is long. A fair average price for roads in Western New York would be $4.30 per cubic yard, or 35¢ per square yard for a three-inch depth.

Depth of Course.

As the top stone is relatively more expensive than the bottom course a good design calls for the least thickness of top which can be successfully constructed and maintained.

In 1901 the thickness used for top-course macadam in Massachusetts, New York, Connecticut, and New Jersey was 2", and the size of the top-course stone fragments ranged from ½" to 1½" in Massachusetts to 1" to 2" in New York. Experience demonstrated that with a course as thin as 2", the larger stone fragments tended to "kick out" under traffic and that the top wore out by raveling rather than by the abrasive action of the teaming. For this reason the best practice at present calls for a 3" depth of finished top course, using stone ranging in size from 1¼" to 2½"; this depth makes it possible for the large stone fragments to interlock more firmly than in a 2" course.

Crowns.

The crowns used on plain macadam are ½" to 1' to ¾" to 1'; while ½" to 1' is satisfactory when first built, the gradual loss of crown due to traffic and weather action soon makes it too flat to shed the water. Mr. Charles Mills, Chief Engineer of the Massachusetts Highway Commission, reports the following loss of crown on State roads in Massachusetts and concludes that an original crown of ¾" to 1' is advisable, except in villages where the traffic is in two lines. A ⅝" to 1' crown has proved satisfactory in New York State.

TABLE 20. TESTS MADE IN DECEMBER, 1901

Date of Original Construction	Number of Tests	Original Crown (Inches per Foot)	Present Crown (Inches per Foot)
1895	7	0.694	0.500
1896	9	0.583	0.514
1897	12	0.645	0.500
1898	7	0.625	0.500
1899	2	0.688	0.625

From the Massachusetts Highway Report for 1901.

Maximum Grades.

Waterbound macadam gives a good footing for horses on the steepest grades that are ever constructed; the limit of grade for this construction is determined by the cost of maintenance; on steep grades macadam washes badly and the cost of maintenance is high. Good practice limits its use to grades of 5% or under, although it has been used and maintained successfully on grades as high as 12%.

Advantages and Disadvantages.

Waterbound macadam does not require particularly rigid inspection during construction and can be built under almost any weather conditions except freezing. By its method of construction the voids between the large stone fragments are completely filled with solid material and there is no tendency to squeeze or creep as in some of

the asphaltic macadams. If carefully built it maintains its longitudinal and transverse shape and is an easy riding road for both team and motor traffic.

Under heavy automobile traffic, however, a plain waterbound macadam is not satisfactory as the machines remove the fine dust particles between the larger stones, leaving a rough surface which "kicks out" under team traffic. For this reason waterbound roads which are receiving much motor traffic are generally being treated with some kind of a dust layer or a bituminous protecting coat, or have been superseded by bituminous macadams, brick, natural asphalts, or some variety of top course that will better resist the wear of automobile travel.

Waterbound Roads Treated with Dust Layers or Protected by Flush Coats.

If waterbound macadam is kept moist by sprinkling with water, rapid disintegration under light machine traffic, traveling at medium speeds, is prevented. For light traffic, city or village streets, this is feasible, but the cost of sprinkling long stretches of country roads is prohibitive, and where the speed is high, as usually occurs on the main improved country roads, sprinkling alone will not satisfactorily protect a plain macadam.

The application of calcium chloride to a road surface keeps the dust down for a longer period than sprinkling with water, as this salt has the property of absorbing moisture from the atmosphere and condensing it on the road surface; on side roads three or four applications a season have kept the surface in good condition. The salt is applied with an ordinary agricultural drill, using about $\frac{3}{4}$ of a pound per square yard for the first application and slightly less for the succeeding applications. In Western New York the cost of the first application, 12′ wide, has been from $60.00 to $70.00 per mile; the succeeding applications cost from $30.00 to $40.00 per mile, making the cost of such treatment, per mile per year, about $150.00. Complaints have been made that the application of too much calcium chloride has caused soreness to horses' feet, but using the quantities given above, no trouble has been experienced, to the writer's knowledge.[1]

The application of calcium chloride does not build up the road or form a wearing cushion that protects the stone; it merely prevents the fine surface dust from being blown away or removed by the machines.

Glutrin.

Glutrin is a trade name for the liquid which is run out of sulphide tanks in the manufacture of pulp; it is distilled and the acids neutralized. It resembles molasses in color and consistency, is soluble in water, and is applied by sprinkling the surface of the road with one part glutrin dissolved in one or more parts of water, using from 0.3 to

[1] We are indebted to Mr. Frank Bristow, Superintendent of Repairs, New York State Department of Highways, for much of the data on Calcium Chloride, Glutrin, and Cold Oiling.

0.5 gallons of the glutrin mixture per square yard treated. The road surface need not be swept if the dust is not more than ¼" deep. It hardens the surface to a certain extent and, apparently, prevents raveling if applied twice during a season on roads receiving a moderately heavy traffic. According to Hubbard an addition of 5% to 15% of semiasphaltic oil to the glutrin prolongs its efficiency, but such an addition tends to produce an oily mud in continued wet weather; glutrin alone does not produce this objectionable condition. Glutrin has been laid in New York State under an agreement with the Robeson Process Company of Ausable Forks, at a cost of $0.04½ to $0.06½ per square yard of surface actually treated.

Cold Oiling.

Macadam surfaces treated with light refined tar or asphaltic oil give a nearly ideal surface in dry weather, but have the serious objection of producing an oily mud in continued wet weather, which is hard to clean from rigs and is ruinous to clothes.

The road to be treated is swept clean of dust and the oil is applied by special sprinklers, using from 0.3 to 0.4 gallons per square yard. The surface must be dry when the oil is applied. It is then covered with a good quality of gravel, No. 2 stone, or dustless screenings. In Western New York the cost has ranged from $0.045 to $0.066 per square yard, including sweeping, materials (oil and covering), and the labor of placing.

On medium traffic roads, one application a season is sufficient and on light traffic roads one application will sometimes last for two seasons.

Hot Tar and Asphaltic Residuum Flush Coats.

Bituminous flush coats are applied by sweeping the macadam carefully to remove all surface dirt as well as the stone or sand filler to a depth of about ½" below the top of the larger stone fragments. On this rough, clean, dry surface a heavy refined tar or a bituminous residuum of the binder grade is spread hot, using from 0.3 to 0.8 gallons per square yard. The binder is applied at temperatures ranging from 250° to 400° F., and is spread either by hand-sprinkling pots or is sprayed on by specially devised pressure sprinklers. It is then covered with a layer of clean No. 2 stone (¾"), or dustless screenings and thoroughly rolled. A well constructed surface of this kind resembles asphalt. It protects the macadam from raveling, is waterproof, forms a surface which takes the wear of the traffic from the large stone fragments, and gives a pleasing appearance. However, it cannot be laid in wet or cold weather; like asphalt, it is slippery and will not give satisfactory footing for horses on grades over 4%, and, unless laid evenly, will develop short, sharp waves or humps, which are very disagreeable for fast-moving automobile traffic. Some engineers advance the argument that by successive applications of such a flush coat a road can be maintained indefinitely *without recapping*, but as far as the writer has been able to observe, *where heavy binders* are spread by hand methods the roads become

humpy from continued treatment of this kind that recapping will necessary to even up the surface on the score of comfort alone. is claimed that a medium heavy bituminous material applied by essure sprinklers overcomes this difficulty.

The cost of flush coats exclusive of covering ranges from \$0.12 to .16 per gallon, or about \$0.09 per square yard. If applied to a acadam road during construction the cost of the plain macadam is creased approximately \$0.10 per square yard, making \$0.45 per uare yard a fair comparative figure for flush coat and waterbound acadam construction.

The crown ordinarily used on flush coat roads is ½″ to 1′.

All bituminous binders have the following practical disadvantages hether applied as surface coats or as binders in bituminous maclams. The composition of residuum products is so complex and so sily varied that, to get uniform results, each shipment must be mpled and analyzed to insure certain required properties. In ating, care must be taken not to char the binder, as this destroys life and effectiveness. They cannot be applied in wet or cold eather, which reduces the length of the construction season, and less evenly spread a rough, humpy road results.

tuminous Macadams.

Bituminous macadams are constructed in two ways, by the peneation method and by the mixing method.

netration Method.

Most of the bituminous roads in New York State have been built this method.

The larger stone fragments, ranging in size from 1″ to 2″, to 1″ to ″, depending on the depth of the course, are spread and rolled; heavy grade of refined tar, residuum bituminous material, or fluxed tural asphalt, is then poured hot, either by hand or machines,[1] to the voids of the stone so that the stone fragments are covered ith a thin coat of bituminous material; No. 2 stone, or dustless reenings are spread over the surface and broomed and rolled until e voids are filled; if a flush coat is to be used the excess filler is oomed off and the surface coat applied in the same manner as scribed for plain macadam. Where the flush coat is not applied, wearing coat of clean screenings is spread over the surface.

The amount of bituminous material used as binder varies from 25 gallons to 1.75 gallons per square yard, depending on the depth the course. The amount used for flush coats ranges from 0.3 to 5 gallons per square yard.

The cost of a one-coat 2″ bituminous top, using 1.25 gallons per uare yard, will range from \$0.35 to \$0.45, and a 3″ one-coat top,

[1] The author has never seen the heavier binders successfully spread by machines a loose top course as required for the penetration method; it is difficult to cond the speed of the machine and prevent overlap; hand methods for the first coat ve been *locally more satisfactory*; for maintenance or second coat work, using *dium heavy oils, machines* are better than hand methods.

using 1.75 gallons per square yard, from $0.50 to $0.60 a square yard. The flush coat using 0.4 gallons per square yard will add about $0.06 to the above costs. For the purpose of comparison with macadam a fair set of prices is,

2″	Bituminous top, one coat of bitumen	$0.40	per square yard
2″	" " flush coat	$0.45	" " "
3″	" " one coat of bitumen	$0.55	" " "
3″	" " flush coat	$0.60	" " "

Mixing Method.

The stone and bitumen are mixed hot, either by hand on mixing boards or by specially designed machine mixers. The mixture is then spread in the same way as sheet asphalt. A flush coat can be used if desired. The 1910 New York State specifications call for 1 cu. yd. of mixed No. 2 stone (¾″) and No. 3 stone (1½″) to 17 gallons bitumen of the binder grade.

The mixing method is, at present, more expensive than the penetration method. So few roads of this character have been built, in New York State, at least, that an attempt to submit any general cost data of which we have personal knowledge would be futile. The following instance may be taken as a fair price; a 3″ mixed bituminous top was laid near Rochester, N. Y., for $1.24 per square yard, including a five-year guarantee. New portable mixers are being put on the market, which will doubtless reduce the cost. The author sees no advantage in the mixing method over the penetration method, for country roads, unless by it the cost can be reduced below $0.50 per square yard. There seems to be no reason why it is necessary to have the bituminous binder effective throughout the full depth of the top course to prevent raveling.

Depth of Top Courses for Bituminous Macadams.

In 1910 New York State adopted a depth of 2″ using 1.25 gallons as binder and 0.5 gallons as flush coat per square yard.

In 1911 a 3″ depth was used with 1.25 gallons per square yard as binder and 0.4 gallons as flush coat.

A 2″ bituminous top will not fail by raveling, the defect mentioned for a 2″ waterbound macadam course, but it has certain constructional difficulties. To construct a 2″ course no stone should be over 2″ in its largest dimension. Because of the tendency to crack under concentrated wheel loads, none of the stone forming the main body of the course should be less than one inch in size. These limits of size are so narrow that difficulty has been experienced in procuring sufficient stone for top when crushing local material and even when the stone is obtained from a commercial plant, the same difficulty is often encountered. Also in spreading such a depth with stone ranging in size from 1″ to 2″, there will be places where the metaling is only one stone deep and the fragments do not fit as closely together nor have the same chance to interlock as in a deeper course. The spaces between these stones are filled with the No. 2 (¾″) size, which wears more rapidly under traffic than the larger pieces and the road

tends to become rougher than would occur if the 1½" stone fitted closer together. This last argument does not apply to flush coat roads.

The argument is often made that a 3" top will last one and one-half times as long as a 2" top because it has one and one-half times as much material, but the life of a top course rarely depends on its total thickness, as it will become so badly out of shape before the general elevation has worn down an inch that it will need recapping.

In attempting to meet these difficulties, 2½" and 3" courses have been built; as far as the author has been able to judge, the 2½" depth remedies the defects.

When pouring bitumen in the penetration method, a pocket of fine stone, dirt, etc., will sometimes hold the binder near the top in too great quantities; during hot weather the bitumen swells and, as the voids are full in these spots, it rises to the surface and forms a hump or wave. This trouble is not so frequent on either 2½" or 3" courses as on the 2" depth.

The writer's present opinion is that a 2½" depth, using about 1.4 gallons bitumen per square yard in one coat, will give satisfaction.

Crowns.

The crowns used on bituminous macadams range from ¼" to 1' to ¾" to 1'; ¼" to 1' is generally used and is apparently satisfactory.

Footing.

A single coat road affords good footing on any grade that will be adopted as suitable for heavy hauling; such a top course will not wash, which makes it easy to maintain on hills.

A flush coat, however, cannot be used to advantage on grades over 4%.

Advantages and Disadvantages.

Bituminous macadam without a flush coat provides good footing for horses; it will not ravel, is easy to repair for small depressions and ruts, is comparatively dustless and keeps its longitudinal and transverse shape well, making a comfortable riding road for fast travel. On the other hand, it will probably wear more rapidly than the flush coat construction as the traffic comes directly on the stone; it is subject to the practical disadvantages of construction of all roads where bituminous materials are used; it is not waterproof when first constructed; this last defect, however, is remedied by the traffic which grinds up the surface wearing coat and forces it into the voids. As a matter of fact, the combined action of traffic and weather puddles the road, and after about six weeks use we can say that the road has a bituminous bond and a water-puddle finish.

Flush coat bituminous macadams are more dustless than the single coat, are more nearly waterproof when first built, look smoother at first, and will probably cost less to maintain. However, they do not give as *good a footing* as the single coat and are liable to develop *waves and humps disagreeable* to fast traffic.

If a flush coat is used there seems to be no advantage in a bituminous binder, as the flush coat alone prevents raveling and, if such is the case, the binder used throughout the depth of the course is a waste of money; a waterbound bituminous flush coat course might better be used. In choosing between a flush coat construction or a single coat bituminous macadam, the author believes that a single coat bituminous macadam is the better design; although it will probably cost more to maintain, the increased safety and comfort to the traveling public is worth the expenditure.

Natural Rock Asphalts.

Sandstones and limestones containing a certain percentage of bitumen are known as rock asphalts. The most common source of supply for the Eastern States is Kentucky, and the product is known as "Kentucky Rock Asphalt." It is a sandstone containing about 7% to 10% of maltha. It is pulverized at the mine and is shipped and applied cold in the following manner: 2" to 2½" of stone, ranging in size from ¾" to 1½", are spread and rolled slightly. The rock asphalt is run through a shredding machine and spread over the stone, using approximately forty pounds per square yard. The whole mass is then thoroughly rolled, preferably with a six or eight ton tandem roller; forty pounds per square yard of pure rock asphalt is then spread as a wearing coat and well rolled; the rolling is continued intermittently for a number of days after the traffic is turned on the road. The cost of such a course has been about $0.70 per square yard in Western New York.

The crown ordinarily used is ½" to 1'.

Advantages and Disadvantages.

The road is pleasing in appearance, is not as slippery as sheet asphalt, and will not ravel under motor traffic. However, it is hard to construct in cold weather, is not uniform, and will ravel in spots. It has defects in common with sheet asphalt of showing wear by developing short humps and hollows disagreeable to fast traffic. The steepest grade on which it can be used advantageously is about 5%, as it becomes slippery in cold weather, and in warm weather it sometimes softens enough to make hard pulling for heavy loads.

Other Surfacings of a Bituminous Nature.

There are any number of patented pavements that can be classed under this head to which this book cannot give space.

Sheet asphalt and the "Warren Brothers' Bitulithic Macadam" are good pavements but are too expensive for consideration except in unusual cases.

"Amiesite," a patented material, made of crushed trap rock coated with asphaltic cement, has been used on some of the New York State roads with good results. It is shipped cold in a friable and granulated state, spread 4" deep loose which rolls to 3"; on this rolled surface amiesite screenings are spread and rolled in. The cost has been

approximately \$1.00 per square yard. It resembles asphalt in appearance and has the advantages and disadvantages of all roads of this class.

Brick Pavements.

The ordinary brick pavement construction is probably familiar to most readers. On a concrete foundation about 6″ in thickness a sand cushion, varying in depth from 1″ to 2″, is spread and the paving brick are laid on this sand bed so as to break joints; the brick are well rolled and the joints filled with sand, cement grout, or paving pitch. Longitudinal expansion joints of pitch are provided next to the curbs or edgings, transverse expansion joints, spaced 30′ to 50′, are used by some designers. The proper provision for expansion in brick pavements is a disputed point.

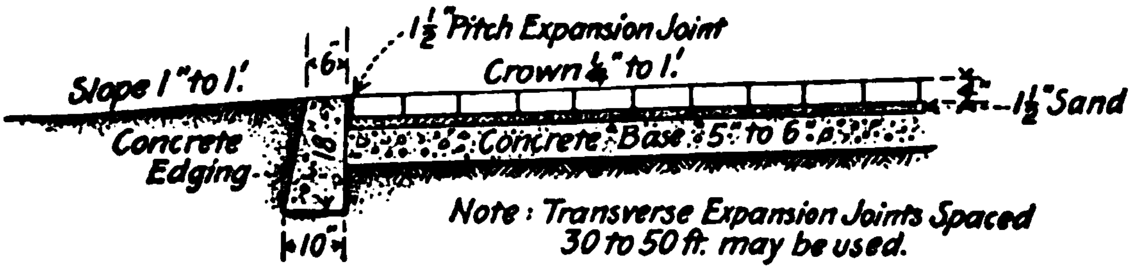


FIG. 26.— Brick Pavement, Flush Edging

The construction is essentially rigid, intended to withstand heavy traffic. The cost, including foundation and surfacing, ranges from about \$1.60 to \$3.00 per square yard, the average price in Western New York being about \$2.00.

Brick pavements on heavy traffic roads have been extensively used in Ohio and New York. Macadam foundations for brick surfacing have not proved satisfactory in the Northern States, as the surface is too rigid and cracks under the heaving action of the frost. Even on a concrete foundation longitudinal cracks often develop from this same action. It is more difficult to prevent this on country roads than in cities where the sewers keep the earth subgrade comparatively dry, and the necessity for a center drain under the concrete base is being recognized by many designers. Some engineers believe that the 1 to 1 cement grout in general use is too strong, and that if a weaker grout or a sand filler were adopted in its place the heavy frost action would merely separate the bricks slightly instead of breaking them and that as the road settled they would fall back into close contact. This is an attempt to make a theoretically rigid construction flexible and seems to be striving to adapt the construction to conditions for which it is not fitted.

Longitudinal Cracks. — These cracks have been carefully studied, as they seem to be the most discouraging feature of brick pavement construction on country roads.

Mr. Wm. C. Perkins, 1st Asst. Engineer, N. Y. S. Dept. of Highways, states from a careful examination of a large mileage of brick roads built under his supervision, that longitudinal cracks have *always occurred within* 2′ or 3′ of the center of the road; that the

cracks extend down through the concrete base and that less difficulty is experienced in preventing them as the crown of the pavement is reduced. From these observations he has been led to experiment with a concrete base having a perfectly flat bottom, as shown in figure 26 A, crowning the road by making the concrete thicker in the middle than on the edges. The claim is made that this style of construction is helping to prevent such cracks.

Transverse Expansion Joints. — The use of transverse expansion joints has not been successful locally. Difficulty has been experienced with the brick loosening at these joints, and whenever a temperature heave has occurred it has appeared at the joint. Their use has been abandoned for rural roads in western New York.

The crowns in use on brick pavements range from ¼" to 1', to ⅜" to 1'. For the methods of figuring ordinates for parabolic crowns see page 225.

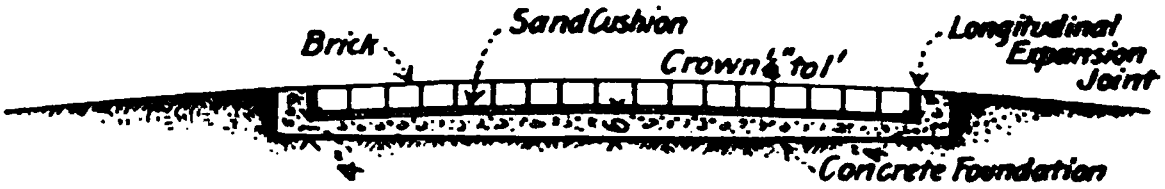


FIG. 26 A

Brick pavement does not give a good foothold for horses on grades above 5% unless some special form of brick is used. For steep grades, on heavy traffic roads, it is better practice to use some form of stone block.

Stone block pavement, including concrete foundation, costs from $2.70 to $3.30 per sq. yd. It is suitable for the steepest grades that are constructed.

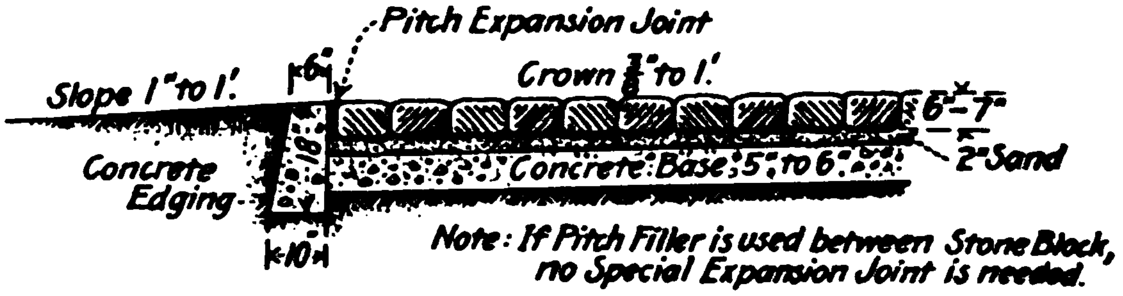


FIG. 27. — Stone Block Pavement, Flush Edging

Where stone blocks are used on hills it is better practice to use second quality blocks; these blocks are identical with the first quality blocks as to material but are not dressed as carefully and cost about fifty cents per square yard less; their rougher surfaces and wider joints afford better footing. For the difference in size and joints see specifications, Medina Block, page 323.

The first cost of brick pavement for country roads restricts its use *to roads where it* can be conclusively proved that macadam will not *be suitable.*

Concrete Pavements.

Solid concrete pavements have been tried, the best known being the "Hassam Pavement," which is, sometimes, specially reinforced to prevent cracks resulting from temperature or heaving. It is understood, however, that both transverse and longitudinal cracks have developed in this type of construction. This seems to be an inherent defect in all rigid types of construction for country roads.

Where the traffic comes directly on a concrete surface it often wears unevenly, failing in spots. This defect has led to the application of a thin wearing coat of bituminous material and stone screenings. How successful this will prove is still to be demonstrated. The cost of such pavements is approximately $1.00 per sq. yd.

Small Stone Block Surfacing.

In Germany, Hungary, Austria, and England a surfacing made of granite blocks, ranging in size from 2½″ to 4″, has been used successfully. This pavement is known as Kleinpflaster in Germany, and as "Durax" armoring in England. The stone cubes must be cut with considerable accuracy in order to give a smooth and durable surface.

The blocks are laid on a thin sand cushion of about ¾″ depth, on either a macadam or concrete foundation; they are thoroughly rammed to give a firm bearing and the joints filled either with clean sand flushed in, or a bituminous filler. The joints do not exceed ¼″ in width. The courses of cubes are laid either diagonally to the direction of the traffic or in concentric rings.

Where the stone is broken by hand the cost is high and it would be impossible to consider its use for rural roads in this country. A machine [1] has, however, been developed in Europe for breaking these cubes which is claimed to produce a satisfactory product at a reasonable rate. It is a belt-driven friction drop-hammer having a stone chisel mounted on the anvil; the hammer head is shaped like a stonecutter's sledge. The power needed for each machine is about 1½ H. P.

About 400 of these machines are in operation, and a plant in Sweden is turning out 700,000 square yards of pavement per year with 62 machines.

Provided the pavement can be laid for $1.00 to $1.25 per square yard, it seems a type that must be seriously considered.

McClintock Cube Pavement.

This is a patented pavement devised by J. Y. McClintock, County Engineer of Monroe County, N.Y. It is very similar to "Kleinpflaster," except that under his patent artificial cubes as well as stone cubes are proposed. It is still in the experimental stage, but appears to be promising, as it is free from many of the difficulties experienced in using bituminous materials and from the rigidity of brick and solid concrete pavements.

The construction is essentially as shown in figure 28, and con-

[1] *A detailed description of this* machine is given in Engineering News, March 28, *1912.*

sists of a top course of 2" cubes placed by hand on an ordinary macadam foundation and filled with sand or sandy loam. The cubes can be readily made of concrete, vitrified paving brick material, or stone, as in Continental practice.

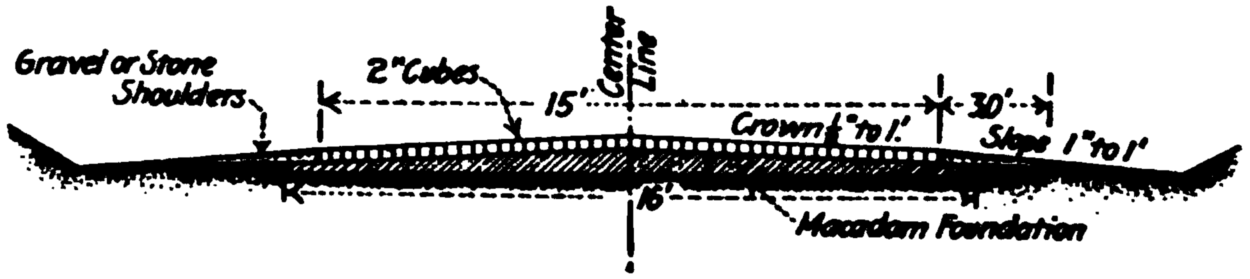


FIG. 28

The cubes are loaded, hauled, and dumped like broken stone. They are laid by hand on a sand cushion $\frac{1}{4}$" to $\frac{1}{2}$" thick, no care being taken to break joints. They are then rolled to bring to an even surface and firm bearing, and a layer of sand or sandy loam is spread on top, broomed and flushed in, preferably with a pipe line and hose; the course is again rolled, the wearing surface of sand placed and the road opened for traffic. Temporary shoulders of 2" plank are put down during the laying of the cubes, after which they are removed and replaced with broken stone or gravel, as shown in figure 28.

A stretch of road one-third of a mile long constructed of concrete cubes, vitrified shale brick cubes, and local clay cubes specially treated has been in use for two years.[1] The surface affords a good footing and is comparatively clean in both wet and dry weather. The cubes have not raveled or broken down at the edges. The concrete cubes have not served satisfactorily, failing in spots, but this is to be expected as it is not a reliable material for road surfacing; the vitrified shale cubes have worn well. It is certain that stone cubes would act well.

The points that particularly appeal to a constructing engineer are the facts that wet or cold weather does not stop construction and that rigid and continuous inspection in laying is not necessary. The facts that appeal to the designer are that he can scientifically arrange his material by placing tougher cubes in the center of the road and softer and cheaper on the sides, that the surface is flexible under frost action, and that the very large item of freight on materials is reduced.

The cost of this surfacing has been:	Concrete cubes	$0.50	per sq. yd.
	Vitrified shale cubes	1.17	" " "
	Local clay ash cubes	1.00	" " "

These costs are high, as the amounts laid were small and involved considerable plant charge and experimental work.

In large quantities it is reasonable to assume that these costs could be reduced from 20% to 30%, which would make their use feasible. With the possibility of cheapening the cost of stone cubes in the near future this style of construction becomes more promising, as it has

[1] A detailed description of this experimental road, near Rochester, N.Y., written by the author, can be found in Engineering News, February 2, 1911.

certain features that appear superior to bituminous macadams or the rigid types of pavements.

Rocmac.

Rocmac is another patented pavement which deserves mention as the roads which the author has seen built by this method compare favorably with other types of construction. The claim is made that, under favorable conditions, it will cost only fifteen cents per square yard more than plain macadam. The only available example of cost details given below is hardly a fair sample of what can be done.

We quote an extract from the 1910 report of the New York State Highway Commission: "Experimental pavement according to the Rocmac System as laid over the westerly portion of Buffalo Road, Section No. 2, County Highway No. 83, located in the Town of Gates, County of Monroe, New York.

"The Rocmac system differs from ordinary macadam construction in that the aggregate of crushed stone is cemented together by a matrix composed of limestone dust (as rich as possible in carbonate of lime) mixed with a solution of silicate of soda and sugar, the silicate of soda combining with the carbonate of lime, an unstable compound, forming silicate of lime, which is a very stable compound.

"The materials used in this experiment were Leroy limestone flour for the matrix, being the entire crusher product which would pass a screen of ¼-inch mesh, and Akron limestone No. 3 size with some No. 4 size mixed for the aggregate. The No. 3 size being retained on a screen of 1¼-inch mesh and passing a screen of 2-inch mesh, the No. 4 size being retained on a screen of 2-inch mesh and passing a screen of 3½-inch mesh.

"The delivery point for material shipped by rail being Coldwater Station, a dead haul of one mile to the beginning of the work.

"The supervision given this work consisted of occasional inspections by the division superintendent of repairs and the inspector in charge of this section, neither of whom could devote much time to this particular work without interfering with other duties. Had the work been constantly directed by a competent foreman more progress would have been made and the cost probably would have been decreased.

"The method pursued during the laying of this surface was to scarify by hand the original foundation course, removing all loose material by brooming, upon this prepared foundation to spread the matrix composed of limestone dust and solution, to an average depth of about two inches, upon this spread the crushed limestone aggregate to such a depth as would give finished rolled thickness averaging about 3¾ inches when properly crowned, then rolling same until thoroughly consolidated and continuing rolling and sprinkling with water by hand until the matrix which flushed to the surface in the form of grout has nearly disappeared, when the pavement is covered with a light coat of screenings and considered complete.

"The *total length of* this resurfacing extending from Station 231 to

Station 275+76 is 3,876 lineal feet, aggregating an area of 6,890 square yards surface upon which was used 1,094 tons of No. 3 and No. 4 crushed limestone, 520 tons of limestone flour and 4,050 gallons of silicate of soda solution.

"Deducting from total expenditure materials not used and expense of labor trimming shoulders and ditching would leave total cost of this resurfacing including all material and labor necessary to form pavement complete in place $6,400.82 or $0.9288 per square yard.

This expense is itemized as follows:

Item	Total	Per Sq. Yd.
Cost of Stone f.o.b. cars delivery point.	$2,026.59	$0.2941
Cost of Rocmac solution.............	617.28	0.0896
Cost of teams hauling stone, solution, water and coal	1,408.79	0.2044
Freight and duty on solution	408.61	0.0593
Roller and coal	547.28	0.0794
Labor	1,341.64	0.1947
Tools, tank, blacksmith, oil and wood..	50.63	0.0074
Total.........................	$6,400.82	$0.9288

"The average price paid per ton for all stone f.o.b. cars at delivery point is $1.25½; price paid per hour for labor $0.22; for teams $0.56¼ per hour; roller rent $10 per day.

"During the progress of this resurfacing traffic was not interfered with at all, all traffic being permitted to go over the work in whatever stage of progress. This is an advantage worthy of consideration.

"The finished surface after five months' traffic has the appearance of a well-constructed macadam road, being hard, smooth, well bound, and clean, no discoloration being apparent except immediately after a rain, when it shows light brown in spots, due to the solution, which being soluble in water comes to the surface.

"No ravel developed during continued dry weather when freshly laid and under traffic; road is relatively dustless; this, however, depends upon the percentage of silica in the stone used. The theory being that whenever the pavement becomes wet the solution is brought to the surface, resulting in absorbing and hardening down any fine material which had been produced by the abrasion of tires.

"It can be laid in all excepting freezing weather, and while smooth yet it is sufficiently rough to afford good footing for horses and rubber tires. There is nothing entering into the construction to soften under high temperature and nothing to form mud in wet weather. It is claimed to be self-healing, due to continual chemical reactions *taking place whenever* the road becomes wet."

›nclusion.

In the foregoing discussion the author has attempted to show the ›proximate costs of the different styles of construction in general ›e or such experimental tops which he has seen that promise well. he costs given can be considered as relative only, to be used in a ›mparison of the various constructions and are based on roads in Western New York.

For medium traffic highways the general tendency of the different tates and the Government Office of Roads seems to be toward ther bituminous flush coats or bituminous binders, using an ordinary ıacadam foundation. There is no doubt that these constructions re good and a great advance over plain macadam where motor affic is encountered, but they have some very objectionable features hich should not be overlooked. Bituminous materials for road ork afford a profitable outlet for much of the tar and asphaltic siduums produced in the manufacture of gas, coke, kerosene, etc., nd an extensive advertising campaign has made this system of nstruction familiar to both road engineers and the general public.

It is not improbable that the tendency, at present nearly universal, ›ward such binders has been given undue impetus in this way to ıe exclusion of other promising types of design.

CHAPTER VI

MINOR POINTS

UNDER this heading are included guard-rail, bridge-rail, retaining walls, toe walls, curbs, guide and danger signs, cobble gutters, rip-rap, catch-basins, grates, and dykes.

Guard Rail (Wooden).

The construction generally used is shown in the following sketch:

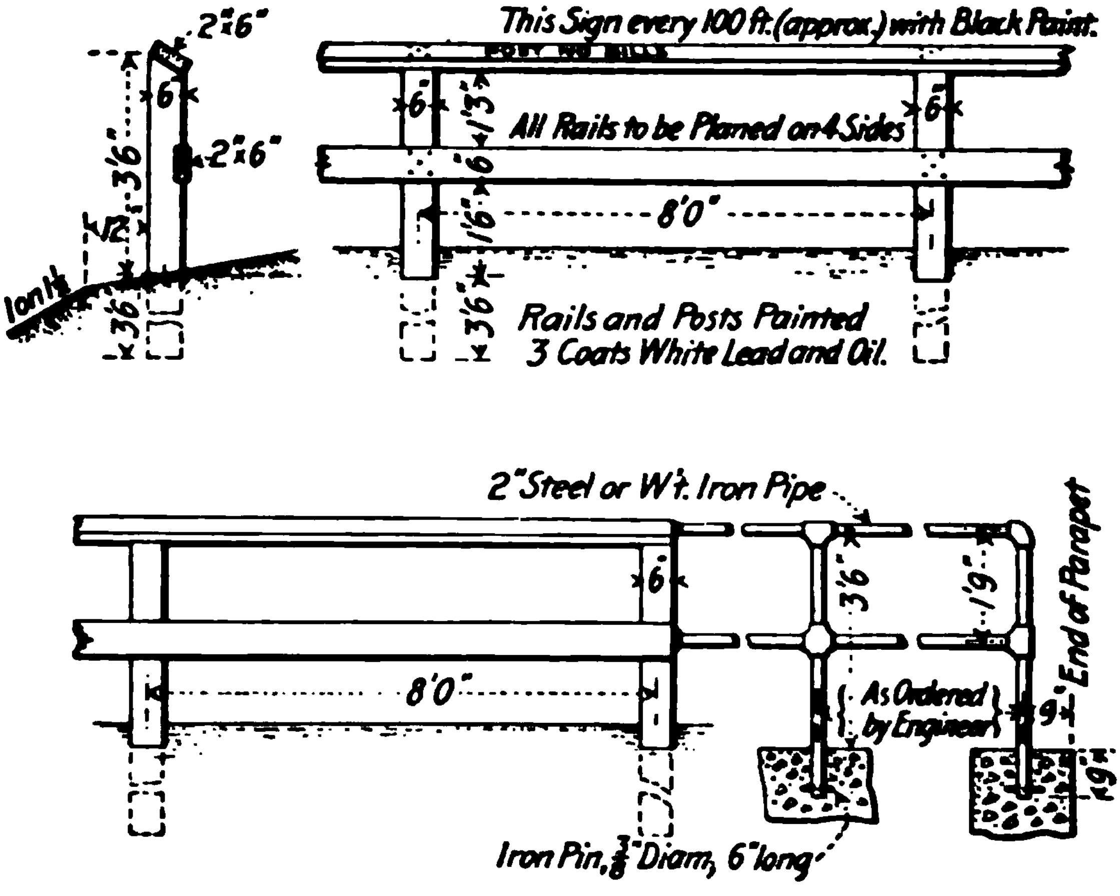


FIG. 29

The posts are cedar, white oak, or chestnut, and the rails are hemlock, yellow pine, or white pine. Such guard-rail costs from twenty-five to forty cents per foot, about five cents per foot per year for maintenance, and needs renewal every eight to ten years: the capitalized cost at 4% is approximately $1.25 as figured by the New York State Highway Commission, and on this basis they have decided that it is cheaper to use a fill slope of 1 on 4 up to a seven-foot depth, eliminating the guard-rail, than it is to use a 1 on 1½ fill slope with guard-rail.

The wooden guard-rail as built acts as a warning only. If a machine or rig becomes unmanageable and hits the rail, it generally breaks or the posts tear out, allowing the vehicle to turn turtle on the fill

pe. So many accidents of this kind occur that there is a demand · a rail that actually gives protection as well as a warning.

ncrete Guard-Rail.

Because of this demand and the high cost of maintenance and ıewal of the common wooden rail, concrete guard-rail is being opted. The simplest and best design of this kind that the author s seen was tried out by the New York State Department of ghways on the Ridge Road, near Rochester, N.Y., in 1910. A etch is given below. This construction has been specially com- :nded by the automobile associations.

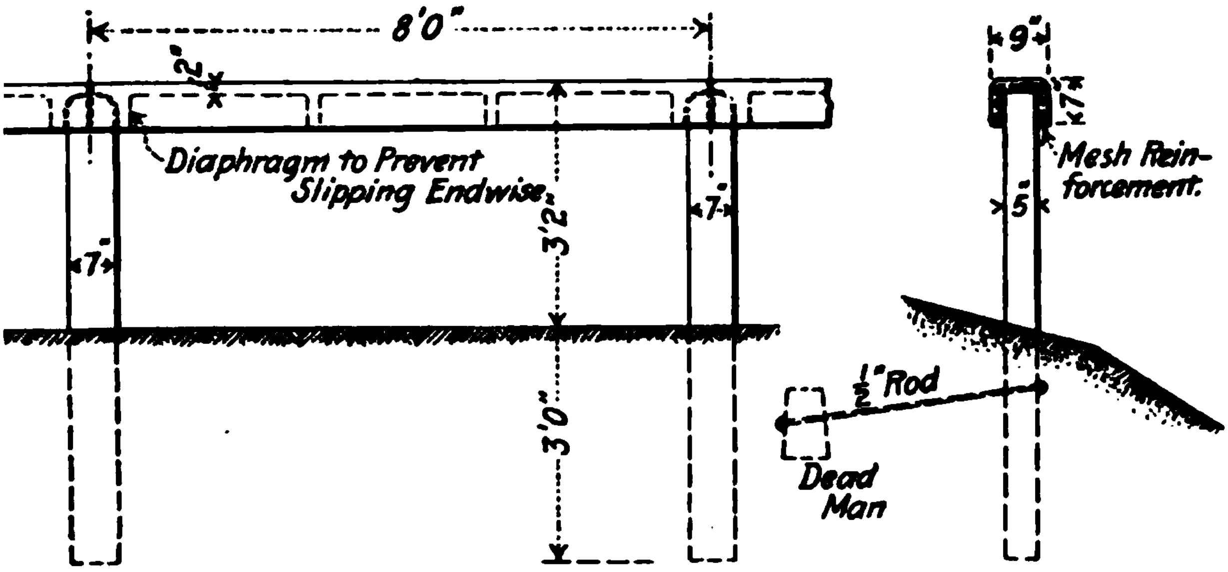
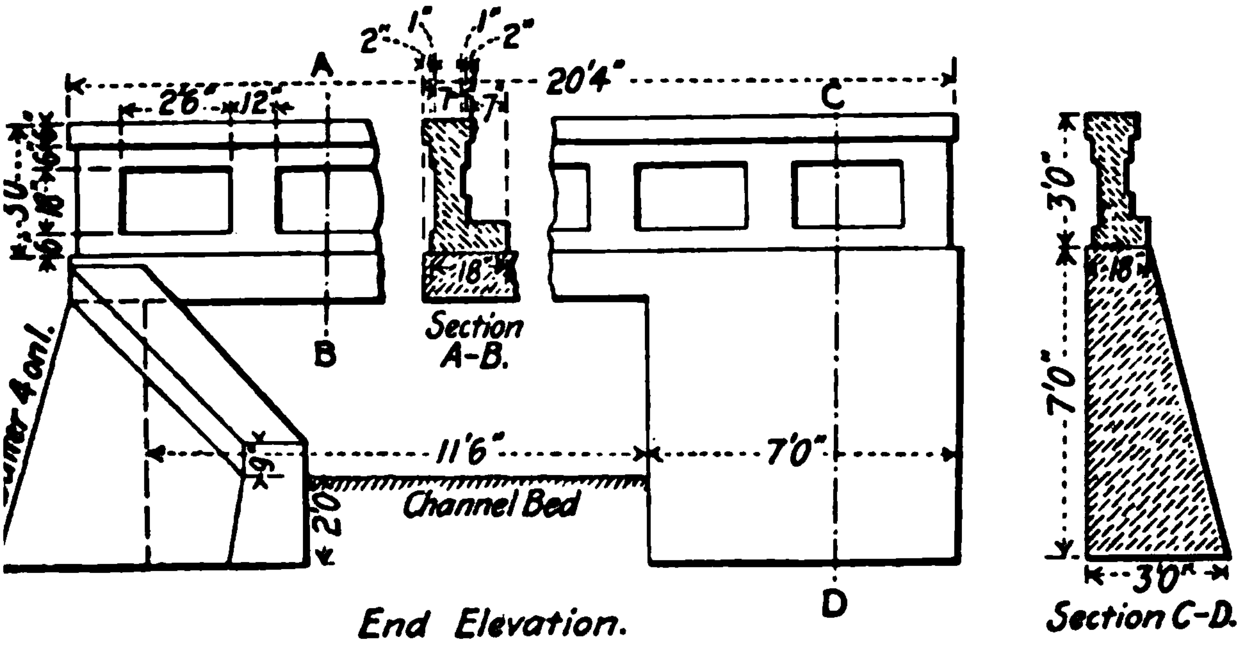
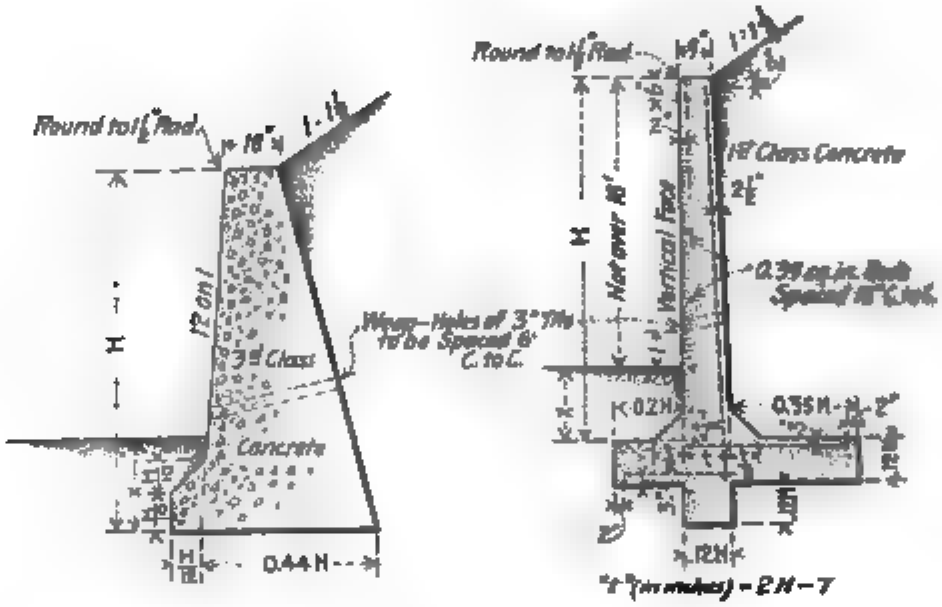


FIG. 30

The rail was invented by J. Y. McClintock, County Engineer of onroe County, N.Y. It is neat in appearance, durable and strong, d is specially adapted for a combination bridge and approach



IG. 31.—Showing Raised Parapet on Skew Bridge extended over Straight Parapet Retaining Wall



Type W. Type R.

FIG. 32.— New York State Standard Retaining Walls

H	Reinforcing Steel Bars of Deformed Section								
	Stem[1]			Heel			Toe		
	Net Area	Spacing C–C	Length	Net Area	Spacing C–C	Length	Net Area	Spacing C–C	Length
11′	0.601	6¼″	12′ 2″	0.442	7½″	4′ 11½″	0.442	9½″	3′-3½″
12′	0.601	5½″	13′ 3½″	0.442	6¼″	5′-5½″	0.442	8¼″	3′-8″
13′	0.601	5″	14′ 5″	0.442	5¼″	6′-0″	0.442	7½″	4′-0½″
14′	0.601	4½″	15′ 6½″	0.601	6¼″	6′ 6″	0.601	8½″	4′-4½″
15′	0.601	4″	16′ 8″	0.601	5¾″	7′-0″	0.601	7½″	4′-9″
16′	0.994	6″	17′-9″	0.601	4¾″	7′-6½″	0.601	6½″	5′-3½″
17′	0.994	5½″	18′ 10½″	0.785	5½″	8′-0½″	0.785	7½″	5′-6″
18′	0.994	5″	20′-0″	0.785	4⅞″	8′ 7″	0.785	6⅞″	5′-10½″
19′	0.994	4½″	21′ 1½″	0.785	4⅞″	9′-1″	0.785	6½″	6′-2½″
20′	0.994	4⅛″	22′ 3″	0.785	4″	9′-7″	0.785	5½″	6′-7″

[1] In each set of 3 bars in stem, first bar which is of length given, extends to top of wall, second bar to height ⅔ H, third bar to height ⅓ H.

When Type W is used as a bank wall (that is, above the roadway), max. H = 20′; min. X = 2′ for H of 5 to 10′; and 0.2 H for H greater than 10′.

When Type W is used as a sustaining wall (that is, below the roadway), max. H = 15′, and min. X = 3′, except where foundation is rock or entirely below frost.

When Type R is used as a bank wall, max. H = 20′; min. X = 0.15 H for H greater than 10′.

When Type R is used as a sustaining wall, max. H = 15′; min. X = 0.25 H for H greater than 10′.

e old design of an iron bridge rail connected with a wooden has been an eyesore.

tual cost of manufacture and setting was from fifty to sixty foot. The contract price for such rail would, probably, run ιty cents to one dollar, depending upon the length of the haul, .te, and difficulty of digging post holes, but even at the high is cheaper than the wooden rail and is a safe construction. ιor and rod shown on the sketch is used on curves or even ht stretches where new fill is encountered, to prevent the ng torn out by impact from runaway machines.

il proper has a web reinforcement; it is designed to stand a orizontal load at the center of the panel. The rails and molded separately and allowed to set for, at least, a month; then put together in much the same manner as the wooden e rounded top of the post makes it possible to erect on any

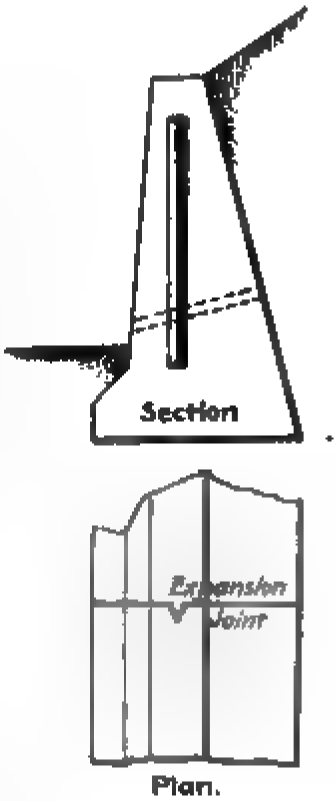
ail and Raised Parapets.

rail for small span bridges is of two types, iron pipe rail e 29) or solid raised parapets (see). The solid parapet is to be pre-

; Walls.

sual cases retaining walls are needed construction. Plain or reinforced walls are generally used, the selec- nding upon the relative cost. The icrete wall is considered the best heights up to twelve feet; the re- cantilever form from twelve feet to feet, and above eighteen feet the d design. We give below examples for the plain and reinforced can- pes only, as the necessity for walls an eighteen feet is very rare For n of buttressed walls the reader is o the standard works on reinforced

ing walls are usually built in mon- ctions of 20′ to 25′ in length, ex- joints are provided between these The expansion joints may consist a plane of weakness between the produced by allowing one section fore building the adjacent wall, or a key joint as shown in figure 32 A, plane of separation may be made nounced by coating the concrete with a thin layer of as- or pitch.



Key Expansion Joint.

FIG. 32 A

Toe Walls.

Toe walls are nothing more than low retaining walls or very substantial curbs. They are used in cuts on the outside of the gutters to prevent unstable side slopes from filling the gutters or heaving them out of shape by sliding pressure. Figure 33 gives a section of Eden Valley Hill near Buffalo, N.Y., where a clay quicksand cut was successfully protected in this manner.

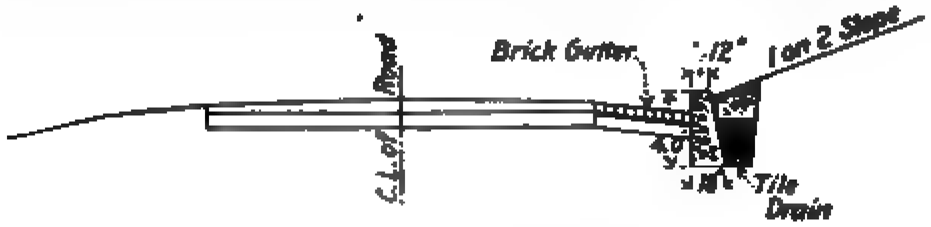


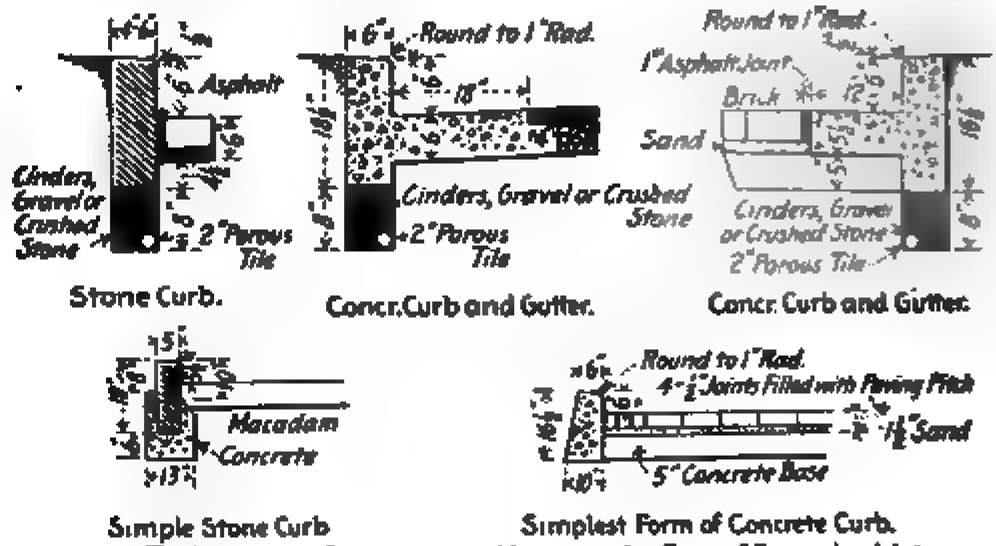
FIG. 33. — Showing Concrete Toe Wall

Curbs.

Curbs are constructed of stone and of concrete.

Stone Curbs.

The cuts given below show the methods of setting; the size of curbstones for first-class work range from 16" to 22" in depth, 5" to 6" in thickness and 3' to 5' in length. For small villages, curbstone of 4" width, set in the simplest manner shown, is satisfactory. The stones most used are granites, bluestones of New York State, and the tougher sandstones such as Medina, Berea, Kettle River, etc. The prices range widely, depending on the locality of the work. Mr. William Pierson Judson, in his "Roads and Pavements," gives the following range of costs:



Stone Curb. Concr. Curb and Gutter. Concr. Curb and Gutter.

Simple Stone Curb For Light Traffic Village Streets.

Simplest Form of Concrete Curb. (Showing also Form of Expansion Joint where Brick are Laid Longitudinally in Gutter.)

FIG. 34

aight curbs set, cost about as follows, with 30 per cent to 50 per added for curves:

nite $0.50 to $0.90, unusual case $1.25 per foot.

ter and Oxford bluestone, $0.40 to $0.80, unusual case $1.00 ot.

dina and Berea sandstone, $0.35 to $0.70.

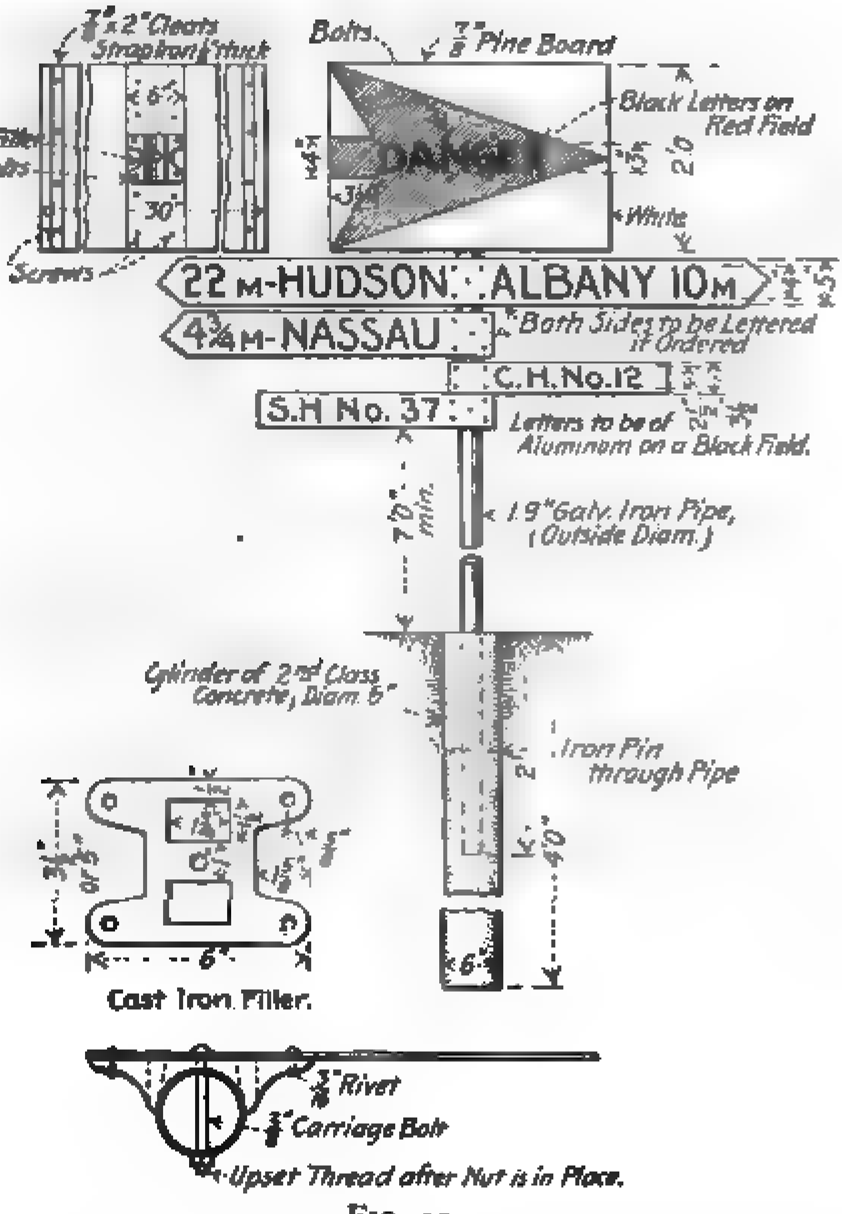
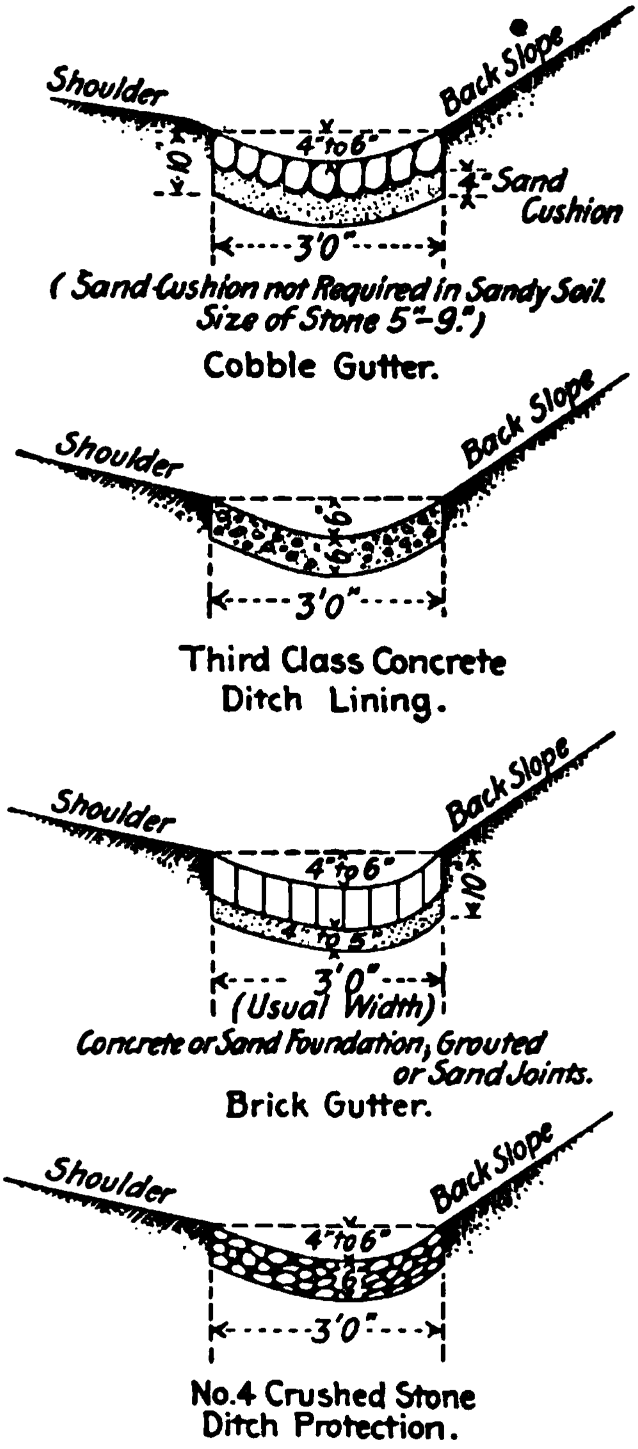


FIG. 35

ncrete usually costs from $0.40 to $0.50 with $0.35 added for a ined gutter, though combined gutter and curb have been built .50.

simple concrete curb (figure No. 34) has been built during in different parts of Western New York at a cost of $0.30 to *per foot.*

Where stone curbs can be built for less than \$0.50 per foot, it i good policy to use them through the business sections of small vill For the residential portic where the cost of stone cu is high, a concrete curb o simplest design is the practice, as city condition requirements are neither n sary nor expected.



Cobble Gutter.

Third Class Concrete Ditch Lining.

Brick Gutter.

No.4 Crushed Stone Ditch Protection.

FIG. 36

Guide Signs and Danger S

A good sign must be to read, pleasing in appeai and permanent. The dra shows one of the designs in the posts are of galvanized and cost about \$5.00 in p the background for the minum is a japanned m the signs cost approxim \$.15 per letter including board.

Danger signs should be only where no doubt exis to their necessity as their i criminate use decreases effectiveness.

Cobble Gutters, Brick Gu Ditch Linings, etc.

Cobble gutters are use protect the ditches from on steep grades and at trances to intersecting i where there is not suffi headroom for a culvert. at the entrances to pr property where the grade of the ditch might be badly cut by vehicles.

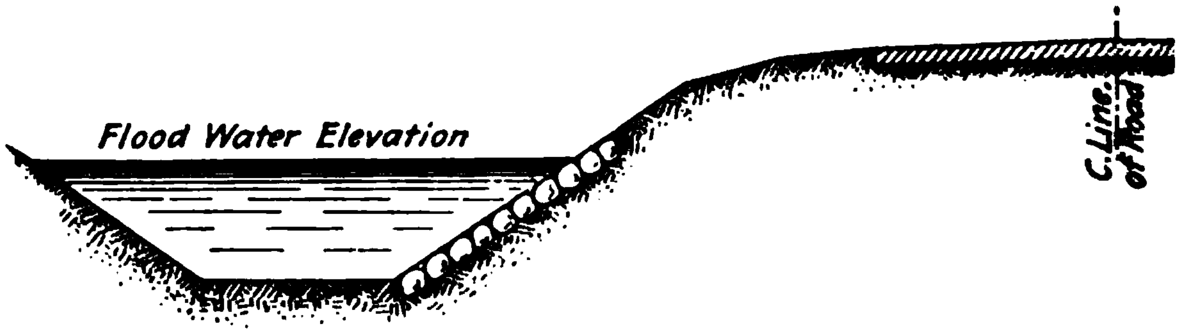


FIG. 37

The usual cost of such construction ranges from \$0.40 to \$1.00 per square yard.

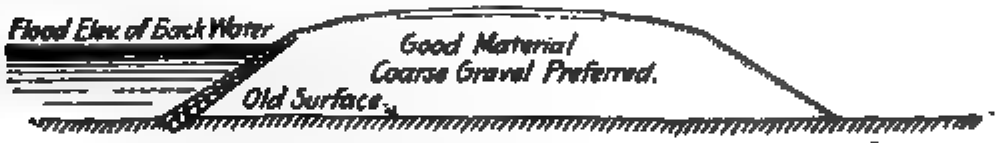


Fig. 38. — Method of Protection where Road can be built above Flood Level

Where cobblestones are not available, ordinary building brick may be used or No. 4 crushed stone, as shown above.

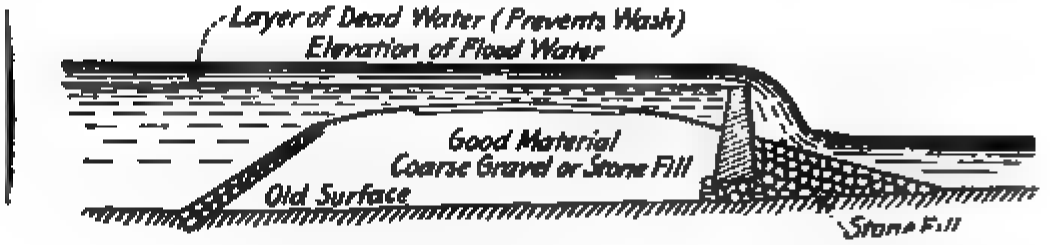


Fig. 39. — Method of Protection where Road cannot be raised above Flood Level

Riprap and Dykes.

Well-constructed riprap protects stream banks and bridge approaches from stream wash except in unusual cases where a solid masonry or concrete protection is required.

The sizes of stone suitable for riprap are usually specified at a

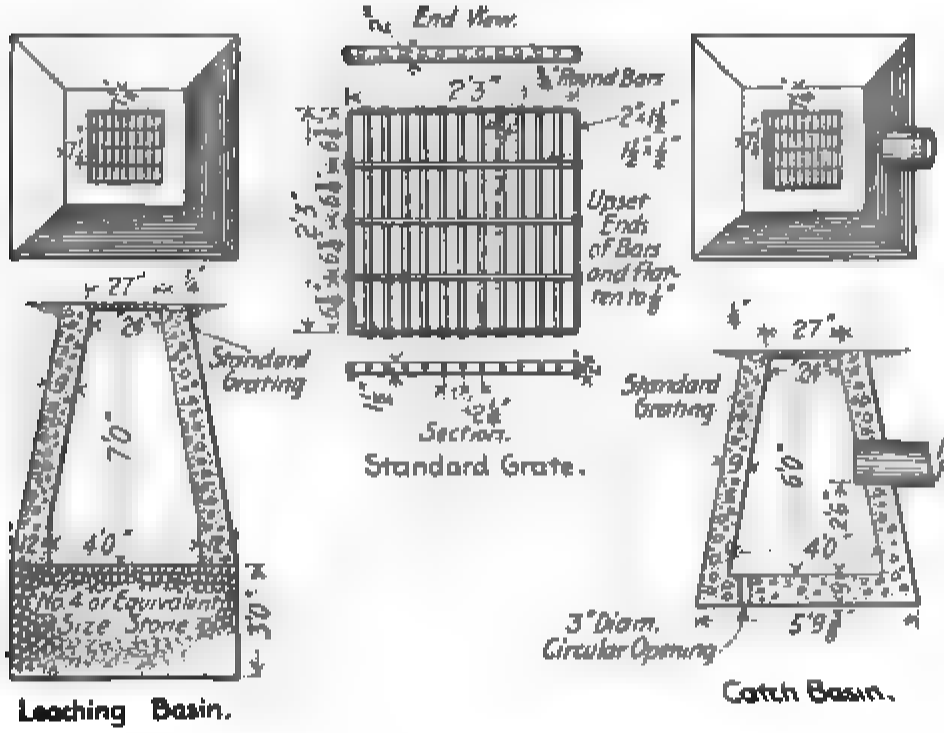


Fig. 40

minimum of ½ cubic foot and 50 per cent or more of the material to be over 2 cubic feet.

Where the road is located in bottom land and is covered with backwater in the Spring, it can be protected by riprap paving on both sides or a dyke and riprap paving on one side as shown in figures No. 38 and No. 39.

Grates.

Cost of cast-iron grates about $0.05 per pound.
Cost of wrought-iron grates about $0.08 per pound.

Repointing Masonry and Refacing Old Walls.

Old masonry structures can often be used complete or in part by repointing the joints; they should be cleaned out thoroughly with a chisel and filled flush with a 1 to 1 Portland Cement mortar.

The author does not believe in facing up old masonry abutments

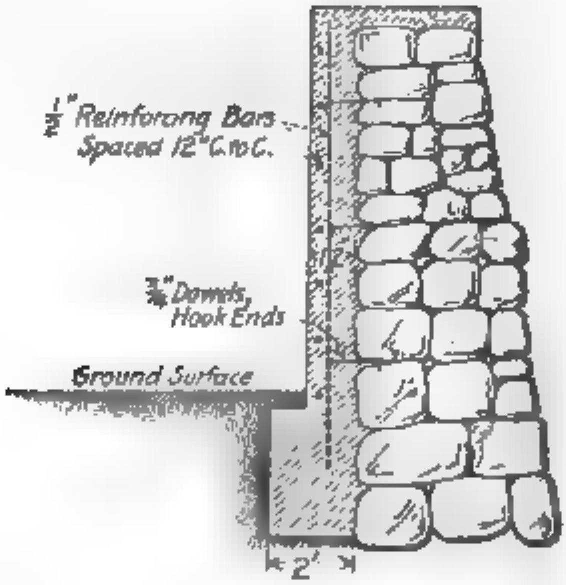


Fig. 41.—Facing for Old Masonry

if it can be avoided; however, if it seems advisable, because of shortage of funds, the old joints should be well cleaned out and hook dowels used as shown in cut No. 41. One dowel every 6 square feet is good practice.

The concrete facing should be at least 12 inches thick and reinforced to prevent settlement and temperature cracks.

CHAPTER VII

MATERIALS

THE selection of materials is an important part of the design. Most municipal and State Departments have well equipped laboratories for testing stone, gravels, brick, bitumens, cements, etc. The object of these tests is to determine the physical and chemical properties that have a particular bearing on the action of the materials under construction conditions. While these conditions are not attained they are approximated and by a comparison of the laboratory results with the actual performance of the different materials in practice a relation can be established that is useful as a basis for judgment:

This chapter gives a brief statement of the desirable qualities and the tests for:

1. Top course, macadam stone.
2. Screenings.
3. Bottom course, macadam stone.
4. Bottom course fillers.
5. Brick.
6. Bituminous binders.
7. Concrete materials.

1. Stone for the Top Course of Macadam Roads

The destructive agencies affecting the top stone are wind, rain, frost, chemical action of the atmosphere, wheels of heavy loaded vehicles, horses' caulks, the suction of automobile tires, and the tractive effort of these machines. Mr. Logan Waller Page, Director of the United States Office of Roads and former Geologist of the Massachusetts Highway Commission, discusses the importance of these factors in the 1900 report of that Commission and shows that the weathering action is so slight compared to the wear due to traffic that it can be disregarded.

To show the resistance of the different rocks to this traffic action, tests are made for: 1st, Impact and Abrasion; 2d, Hardness; 3d, Toughness; 4th, Cementing Value; 5th, Absorption; 6th, Specific Density, and 7th, Geological Classification. The standard methods of testing used by the American Engineers in 1910 are described as follows:

Impact and Abrasion.

The impact and abrasion test is made in a Deval rattler, a picture of which is given below. The cast-iron cylinders, a, b, c, and d, are 34 cm. deep, 20 cm. in diameter, and inclined at an angle of 30 degrees with the shaft; 5 kg. of clean dry stone, ranging in size from 1½

inches to 2½ inches, are placed in one of these cylinders, and the machine is rotated 10,000 times at the rate of 2,000 revolutions per hour; as the shaft revolves the stone is thrown from end to end of the retort. At the end of five hours the charge is removed and all stone retained on a 0.16 cm. sieve is washed and dried; the loss by abrasion is then the difference in weight between the original charge and the residue above 0.16 cm. in size.

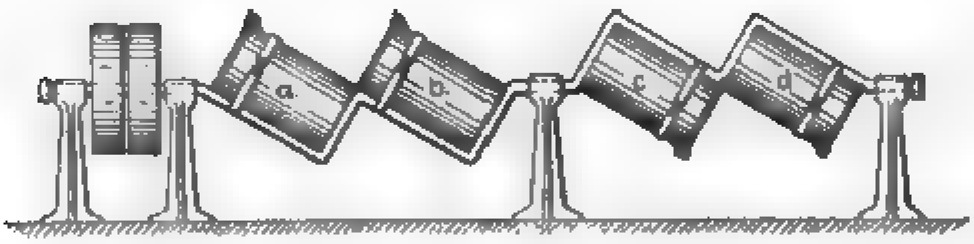


FIG. 42. — Deval Rattler

Hardness.

Hardness is determined by a Dorry machine. A stone cylinder 25 cm. in diameter, obtained by a diamond core drill from the material to be tested, is weighed and placed in the machine so that one end rests on a horizontal cast-iron grinding disk with a pressure of 25 grams per sq. cm. The disk is revolved 1 000 times during which standard crushed quartz sand, about 1½ mm. in diameter is automatically fed to it. The cylinder is then removed and weighed and the coefficient of hardness obtained by the formula $20 - \frac{1}{3}$ the loss in weight, expressed in grams. In order to get reliable results two cylinders are generally used, each one being reversed end for end during the test.

Toughness.

Toughness is determined as follows: A core similar to that used for the hardness test is divided by a lapidary saw into lengths of 25 mm. These are placed in an impact machine and broken by blows of a 2-kg. hammer transmitted through a 1-kg. weight. The drop of the hammer for the first blow is 1 cm., increasing at the rate of one additional cm. for each blow. The coefficient of toughness equals the number of blows required to break the test piece.

Cementation.

One kilogram of fine stone that passes a 6 mm. sieve and is retained on a 1 mm. sieve is moistened and placed in an iron ball mill containing two 25-lb. chilled-iron balls; the mill is revolved at the rate of 2,000 times per hour for 5,000 revolutions, which reduces the charge to a thick dough. Twenty-five grams are then placed in a cylindrical die and put under pressure of 100 kg. per sq. cm. The briquette is removed, dressed to a length of 25 mm. and dried in the air 12 hours and for 12 hours at a temperature of 100° C. When cool it is tested in an impact machine in a similar manner as for toughness, using a 1 kg. hammer and a fixed height of fall of 1 cm. The average of five samples is the value adopted.

ion is calculated from an immersion of 96 hours, using a nent that has been subjected to the abrasion test, and is is pounds of water per cubic foot of rock.

avity.

gravity is calculated in the usual way by dividing the a fragment of the stone in the air by its loss of weight in

Classification.

ological classification is made from a microscopic and ialysis.

s suitable for road work must crush with a rough jagged i order to interlock firmly under the action of the roller. ue of the cementation test is doubtful, as it is comparatively according to Mr. A. Armstrong, Chief of the Bureau of New York State Department of Highways, does not seem ith practice. The other tests are, however, reliable guides. iting action of the screenings need not be considered where t, or other binders of this type are used, and is not as im- r waterbound roads with flush tar coats as for the plain

: of collecting and testing stone as given in the 1909 Report r York State Department of Highways is $8.55 per sample. No. 21, No. 22, and No. 23 show the results of tests on the non rocks.

TABLE 21. TAKEN FROM BULLETIN NO. 31, UNITED STATES OFFICE OF PUBLIC ROADS

Rock varieties	Per cent wear	Toughness	Hardness	Cementing value	Specific gravity
Granite	3.5	15	18.1	20	2.65
Biotite-granite	4.4	10	16.8	17	2.64
Hornblende-granite	2.6	21	18.3	30	2.76
Augite-syenite	2.6	10	18.4	24	2.80
Diorite	2.9	21	18.1	41	2.90
Augite-diorite	2.8	19	17.7	55	2.98
Gabbro	2.8	16	17.9	29	3.00
Peridotite	4.0	12	15.2	28	3.40
Rhyolite	3.7	20	17.8	48	2.60
Andesite	4.7	11	13.7	189	2.50
Fresh basalt	3.3	23	17.1	111	2.90
Altered basalt	5.3	17	15.6	239	2.75
Fresh diabase	2.0	30	18.2	49	3.00
Altered diabase	2.5	24	17.5	156	2.95
Limestone	5.6	10	12.7	60	2.70
Dolomite	5.7	10	14.8	42	2.70
Sandstone	6.9	26	17.4	90	2.55
Feldspathic sandstone	3.3	17	15.3	119	2.70
Calcareous sandstone	7.4	15	8.3	60	2.66
Chert	10.8	15	19.4	27	2.50
Granite-gneiss	3.8	12	17.7	26	2.68
Hornblende-gneiss	3.7	10	17.1	30	3.02
Biotite-gneiss	3.2	19	17.5	41	2.76
Mica-schist	4.4	10	17.8	30	2.80
Biotite-schist	4.0	—	—	16	2.70
Chlorite-schist	4.2	—	—	24	2.90
Hornblende-schist	3.7	21	16.5	53	3.00
Amphibolite	2.9	10	19.0	29	3.00
Slate	4.7	12	11.5	102	2.80
Quartzite	2.9	19	18.4	17	2.70
Feldspathic quartzite	3.2	17	18.3	21	2.70
Pyroxene quartzite	2.3	27	18.6	17	3.00
Eclogite	2.4	31	17.4	21	3.30
Epidosite	3.6	16	16.0	47	3.03

Names of Rocks		No. of Tests	Impact and Abrasion			Cementing Value			Weight in Lbs. per Cu. Foot	Water Absorbed Lbs. per Cu. Foot
Common	Scientific		Max.	Min.	Mean	Max.	Min.	Mean		
Trap	Basalt	3	2.15	1.31	1.65	31	16	23.5	187	0.14
Trap	Diabase	33	4.31	1.31	2.21	62	13	29.4	184	0.19
Trap	Diabase porphyry	5	2.72	1.81	2.21	—	17	—	182	0.12
Trap	Unidentified	15	4.48	1.52	2.46	53	18	30.6	185	0.22
Trap	Hornblende syenite	3	3.17	2.07	2.53	—	11	—	181	0.12
Porphyry	Felsite	9	3.25	2.01	2.77	101	16	42.6	167	0.19
Sandstone	Sandstone	9	4.18	1.71	2.87	20	10	13.2	170	0.61
Sandstone	Quartzite	5	4.41	1.97	3.19	—	14	—	166	0.18
Granite	Hornblende granitite	17	4.64	1.90	3.03	77	8	23.4	175	0.20
Granite	Granite	9	4.76	2.23	3.50	14	5	8.8	166	0.22
Granite	Gneiss	14	7.98	1.73	4.34	28	1	12.6	172	0.17
Granite	Gabbro	1	—	—	5.36	—	12	—	185	0.71
Field stones	Coarse drift materials	82	8.22	2.08	4.12	46	5	16.6	—	—
Limestones	Limestone	12	6.34	2.10	4.04	26	8	16.0	170	0.26
Limestones	Limestone	9	6.45	2.90	4.69	94	15	53.7	—	—
Schist	Schist	7	8.20	3.27	4.28	—	16	—	178	0.11
Gravel	Crushed gravel	1	—	—	3.01	—	10	—	—	—
Slate	Cambrian slate	1	—	—	4.72	—	—	—	—	—
Flint	Chert	1	—	—	4.79	—	—	—	—	—
Marble	Marble	1	—	—	14.01	—	—	—	—	—

[1] Baker's "Roads and Pavements."

TABLE 23. TAKEN FROM JUDSON'S CITY ROADS AND PAVEMENTS, PAGE NO. 149

Kind	Number of Tests	Percentage of Loss by Abrasion		
		Maximum	Minimum	Mean
Diabase trap	35	4.31	1.40	2.28
Limestone	24	6.68	2.33	4.34
Granite	10	4.30	2.23	3.52
Quartzite	7	5.90	1.97	3.63
Gneiss	12	6.57	1.73	4.01
Sandstone [1]	12	6.69	1.71	3.56

TABLE 24.[2] GEOLOGICAL CLASSIFICATION.

Class	Type	Family
I Igneous	1 Intrusive (plutonic)	*a* Granite
		b Syenite
		c Diorite
		d Gabbro
		e Peridotite
	2 Extrusive (volcanic)	*a* Rhyolite
		b Trachyte
		c Andesite
		d Basalt and diabase
II Sedimentary	1 Calcareous	*a* Limestone
		b Dolomite
	2 Siliceous	*a* Shale
		b Sandstone
		c Chert (flint)
III Metamorphic	1 Foliated	*a* Gneiss
		b Schist
		c Amphibolite
	2 Nonfoliated	*a* Slate
		b Quartzite
		c Eclogite
		d Marble

[1] *Includes Medina* sandstone at 2.29 and Ulster bluestone at 3.71.
[2] *Bulletin No. 31,* United States Department of Public Roads.

The following quotation from this same bulletin describes the characteristics of the three groups:

Igneous Rocks.

"All rocks of the igneous class are presumed to have solidified from a molten state, either upon reaching the earth's surface or at varying depths beneath it. The physical conditions, such as heat and pressure, under which the molten rock magma consolidated, as well as its chemical composition and the presence of included vapors, are the chief features influencing the structure. Thus, we find the deep-seated, plutonic rocks coarsely crystalline with mineral constituents well defined, as in case of granite rocks, indicating a single, prolonged period of development, whereas the members of the extrusive or volcanic types, solidifying more rapidly at the surface, are either fine-grained or frequently glassy and vesicular, or show a porphyritic structure. This structure is produced by the development of large crystals in a more or less dense and fine-grained ground mass, and is caused generally by a recurrence of mineral growth during the effusive period of magmatic consolidation.

"In the arrangement of the rock families from a mineralogical standpoint it will be noted that the plutonic rock types, granite, syenite, and diorite, are represented by their equivalent extrusive varieties, rhyolite and andesite, and that diabase has been included, somewhat arbitrarily, with basalt, as a volcanic representative of gabbro. These latter rocks are of special interest, owing to their wide distribution and general use in road construction. They occur in the forms of dykes, intruded sheets, or volcanic flows, and vary in structure from glassy-porphyritic (typical basalt) to wholly crystalline and even granular (diabase). Their desirable qualities for road-building are caused to a large extent by a peculiar interlocking of the mineral components (ophitic structure), yielding a very tough and resistant material well qualified to sustain the wear of traffic.

"Igneous rocks vary in color from the light gray, pink, and brown of the acid granites, syenites, and their volcanic equivalents (rhyolite, andesite, etc.) to the dark steel-gray or black of the basic gabbro, peridotite, diabase, and basalt. The darker varieties are commonly called trap. This term is in very general use and is derived from *trappa*, Swedish for stair, because rocks of this kind on cooling frequently break into large tabular masses, as may be seen in the exposures of diabase on the west shore of the Hudson River from Jersey City to Haverstraw.

Sedimentary Rocks.

"The sedimentary rocks as a class represent the consolidated products of former rock disintregation, as in the case of sandstone, conglomerate, shale, etc., or they have been formed from an accumulation of organic remains chiefly of a calcareous nature, as is true of limestone and *dolomite*. *These* fragmental or clastic materials have *been transported by* water and deposited mechanically in layers or

the sea or lake bottoms, producing a very characteristic bedded or stratified structure in many of the resulting rocks.

"In the case of certain oolitic and travertine limestones, hydrated iron oxides, siliceous deposits, such as geyserite, opal, flint, chert, etc., the materials have been formed chiefly by chemical precipitation and show generally a concentric or colloidal structure.[1] Oolitic and pisolitic limestones consist of rounded pealike grains of calcic carbonate held together by a calcareous cement. Travertine is the so-called 'onyx marble' of Mexico and Arizona. It is a compact rock, concentric in structure and formed by the precipitation of carbonate of lime from the waters of springs and streams.

"Loose or unconsolidated rock débris of a prevailing siliceous nature comprise the sands, gravels, finer silts, and clays (laterite, adobe, loess, etc.). Shell sands and marls, on the other hand, are mainly calcareous, and are formed by an accumulation of the marine shells and of lime-secreting animals. Closely associated with the latter deposits in point of origin are the beds of diatomaceous or infusorial earth composed almost entirely of the siliceous casts of diatoms, a low order of seaweed or algæ.

"This unconsolidated material may pass by imperceptible gradations into representative rock types through simple processes of induration. Thus clay becomes shale, and that in turn slate, without necessarily changing the chemical or mineralogical composition of the original substance.

"Such terms as flagstone, freestone, brownstone, bluestone, graystone, etc., are generally given to sandstones of various colors and composition, while puddingstone, conglomerate, breccia, etc., apply to consolidated gravels and coarse feldspathic sands.

"The calcareous rocks are of many colors, according to the amount and character of the impurities present.

Metamorphic Rocks.

"Rocks of this class are such as have been produced by prolonged action of physical and chemical forces (heat, pressure, moisture, etc.) on both sedimentary and igneous rocks alike. The foliated types (gneiss, schist, etc.) represent an advanced stage of metamorphism on a large scale (regional metamorphism), and the peculiar schistose or foliated structure is due to the more or less parallel arrangement of their mineral components. The non-foliated types (quartzite, marble, slate, etc.) have resulted from the alteration of sedimentary rocks without materially affecting the structure and chemical composition of the original material.

"Rocks formed by contact metamorphism and hydration, such as hornfels, pyroxene marble, serpentine, serpentineous limestone, etc., are of great interest from a petrographical standpoint, but are rarely of importance as road materials.

"The color of metamorphic rocks varies between gray and white *of the purer marbles* and quartzites to dark gray and green of the

[1] *G. P. Merrill's* "Rocks, Rock Weathering, and Soils," 1897, pp. 104–114.

gneisses, schists, and amphibolites. The green varieties are commonly known as greenstones, or greenstone schists."

An examination of the foregoing tables shows that the volcanic igneous rocks commonly called traps and porphyry make the best road material, as they are tough, hard, dense, and crush with irregular rough surfaces.

Of the plutonic igneous granites, the syenites are satisfactory if they contain small amounts of mica and quartz and are not weathered.

The calcareous sedimentary rocks as represented by the harder varieties of limestone and dolomite have been used extensively and have worn well on the secondary roads.

Of the siliceous sedimentary rocks the harder sandstones, such as "Medina," "Ulster Bluestone," "Kettle River," etc., are well adapted for top courses, especially with asphalt or tar binders. Shale is worthless on account of the rapid wear when wet. Chert is too brittle to be satisfactory.

Of the foliated metamorphic rocks gneiss is the most often used. Much of it, however, contains an excess of mica, quartz, and feldspar, which spoils it for road material.

Of the nonfoliated metamorphic rocks quartzite is the most useful, but it is not widely distributed and is often too soft.

Field-stone hardheads which have been distributed by glacial action make a good material for the unimportant roads. They are a mixture of granites, sandstones, limestones, etc., and vary greatly in their properties; the chief argument against their use is the difficulty in separating the different kinds to get a uniform grade of stone. Uniformity of character is important for the top-course material, as a relatively softer rock that is uniform will wear more evenly than a mixed grade of harder rock, which tends to pit. Hardheads less than 6 inches in diameter should not be used, as the crushed fragments have too much smooth rounded surface to lock well.

Conclusion.

To be suitable for top-course macadam any rock must be hard, tough, and dense, must crush with an irregular jagged fracture, and be uniform in character.

The first cost often governs the selection, and the writer believes it is good policy to use the best available local material when the road movement in any locality is just starting, resurfacing with a better grade of stone as the necessity is demonstrated, and that where road work is well understood by the people and a system has been partially completed it is better to use the material that has proved cheapest in the long run.

2. Screenings

Screenings act as a filler and binder for waterbound macadams and as a partial filler for bituminous macadams. The bonding power of screenings is largely mechanical.

The test for the cementing power of the different rock dusts is described in the beginning of this chapter, and the values determined in the laboratory are given in Tables No. 21 and No. 22.

In plain waterbound roads it is often necessary to mix some limestone screenings, fine sandy loam, or even a small percentage of clay loam with trap, granite, sandstone, quartzite, or gneiss screenings to get a good bond and prevent raveling in dry weather.

3. Bottom Course Macadam Stone

As the bottom stone simply spreads the wheel loads transmitted through the top course and is not directly subjected to the traffic action, almost any stone that breaks into cubical irregular shapes that will not air or water slake and that is hard enough to stand the action of the roller during construction will be satisfactory.

Any of the materials listed above in Table No. 24 except shale and slate can be used, provided that they are not rotten from long exposure in the air. The different available varieties are usually tested in the same manner as for top stone in order to pick the best.

4. Fillers

Fillers are used in the bottom course to fill the voids between the crushed stone and to prevent rocking or sidewise movement of the larger pieces.

They should be easy to manipulate in placing, should not soften when wet, or draw water up from the subgrade by capillary action.

The materials most used are

Coarse sandy loam
Coarse sand
Gravel with large excess of fine material
Stone screenings

The fitness of the material can be determined by inspection and by wetting a handful; if it gets sticky or works into a soft mud it should not be used.

5. Vitrified Brick

Bricks must withstand the same destructive agencies as described for top stone. They must be uniform in size, tough, hard, dense, evenly burned, and, on account of their peculiar shape, must have a high resistance against rupture. These properties are tested by the standard methods adopted by the American Brick Manufacturers' Association, as described in the New York State specifications on page 321.

It should be understood that bricks suitable for paving are manufactured in a different way and of different materials than ordinary building bricks.

"The materials for molding any paving brick must be of a peculiar character which will not melt and flow when exposed to an intense heat for a number of days but will gradually fuse and form vitreous *combinations* throughout while still retaining its form.

"*The resulting brick* must be a uniform block of dense texture in *which the original* stratification and granulation of the clay has been

wholly lost by fusion which has stopped just short of melting the clay and forming glass.

"The clay while fusing must shrink equally throughout, thus causing the brick to be without laminations or of any exterior vitrified crust differing from the interior."[1]

The great majority of paving brick are made in Ohio, Illinois, Indiana, Pennsylvania, West Virginia, and New York. They are classed as shale or fire-clay brick.

6. Bituminous Binders

The subject of bitumens is an intricate one and the reader is referred to the works of Clifford Richardson, Prevost Hubbard, and others, for detailed information, as a book of this character can give only an outline.

There are a number of dust preventives and road binders on the market which depend for their effectiveness on a bituminous binding base. The term bitumen is applied to a great many substances. Hubbard arbitrarily defines bitumens as "consisting of a mixture of native or pyrogenetic hydrocarbons and their derivatives, which may be gaseous, liquid, a viscous liquid, or solid, but if solid melting more or less readily upon the application of heat, and soluble in chloroform, carbon bisulphide, and similar solvents."[2]

The bitumens may be classified as native and artificial. The native bituminous materials, that are used in road work, are the asphaltic and semi-asphaltic oils (dust layers), Malthas (the binding base of Rock Asphalts), Trinidad, Bermudez California, and Cuba asphalts, Gilsonite, and Grahamite (which, however, are too brittle in their natural state and require fluxing with a suitable residual oil before they can be used as binders). The natural asphalts are refined to remove water and any objectionable amount of impurities by heating until the gases are driven off, skimming the vegetable matter which rises to the surface, and removing the mineral constituents which fall to the bottom. These fluxed binders are the best heavy binders on the market, but are not in general use on rural roads as they are more expensive than the residuum bitumens.

The artificial bituminous materials are derived by the destructive distillation of coal, or by fractional distillation of crude coal tars, or the native petroleum oils. They comprise the crude coal and water gas tars, the refined tars, the residual oils and semi-solid binders derived from the petroleum oils. They vary greatly in consistency and binding power.

The following material is briefed from Bulletin No. 34, United States Office of Public Roads: The light oils and tars have a relative small percentage of bituminous base and are effective only so long as it retains its binding power; the more permanent binders contain a larger percentage of bitumen; these are the heavy oils and semi-solids.

[1] *Judson's* "Roads and Pavements." page 87.
[2] "*Dust Preventives* and Road Binders." John Wiley & Sons.

Artificial Bitumens.

Crude Tars. Coke ovens and gas plants produce most of the coal tars in use. These tars contain various complex combinations of carbon, hydrogen, and oxygen and small amounts of nitrogen and sulphur. They vary in composition according to the material from which they are made and the temperature at which they are distilled. The percentage of free carbon ranges from 5 per cent to 35 per cent, and the bitumen from 60 per cent to 95 per cent, depending on the temperature of manufacture. Tars produced at high temperatures contain free carbon in excess which weakens their binding power; they, also, contain a large amount of anthracine and napthalene, two useless materials from the standpoint of road work. Tars produced at low temperatures are to be preferred. Coke tar is low temperature tar; gas tar is high temperature tar.

Refined Tars.

Much of the road tar is refined tar — that is, it has been subjected to fractional distillation to remove the valuable volatile compounds. The residuum from this process is a thick viscous material known as coal-tar pitch, and if the crude tar from which it is obtained was produced at a low temperature it is nearly pure bitumen; the dead oils obtained from the distillation are of little value and are often run back into the pitch, which makes it liquid when cold. The following table gives the approximate composition of water-gas tar, crude coal-tar, and refined tar.

TABLE 25. SPECIFIC GRAVITY AND COMPOSITION OF TAR PRODUCTS

Table from Bulletin No. 34 United States Office of Public Roads

Kind of Tar	Specific Gravity	Ammoniacal Water	Total Light Oils to 170° C.	Total Dead Oils 170° 270° C.	Residue (by Difference)
		%	%	%	%
Water-gas tar . . .	1.041	2.4	*a*21.6	*b*52.0	*c*24.0
Crude coal tar . .	1.210	2.0	*d*17.2	*e*26.0	*f*54.8
Refined coal tar .	1.177	0.0	*b*12.8	*g*47.6	*f*39.6

a Distillate mostly liquid.
b Distillate all liquid.
c Pitch very brittle.
d Distillate mostly solid.
e Distillate one-half solid.
f Pitch hard and brittle.
g Distillate one-third solid.

Table 25 A gives a more up-to-date analysis of the coal tars on the market.

The tests and detailed requirements for light, medium, and heavy bitumens are given in specifications, page 311.

If the tar is used as a temporary dust-layer only, it should be a *low-temperature*, dehydrated tar, liquid when cold. If used as a more *permanent binder* and applied hot, it should have a larger percentage

of pitch, should contain no water, and be free from an excessive amount of fixed carbon. If used as a mastic in bituminous macadam, it should contain a high percentage of pitch and be free from the defects mentioned.

Natural Bitumens and Artificial Residual Oils and Semi-Solids.

Mineral oils can be classed as paraffin petroleums, mixed paraffin and asphaltic petroleums and asphaltic petroleums. The relative value of oils as a source of supply for road materials depends on their percentage of asphaltic residue. The eastern oils found in New York, Pennsylvania, West Virginia, etc., are paraffin petroleums; the western oils vary from light to heavy asphaltic petroleums, and the southern oils have a mixed paraffin and asphaltic base.

The crude petroleum is refined by fractional distillation to obtain its valuable products, such as kerosene, etc. The character of the residue depends, as for the tars, on the crude material and the method of manufacture; the operation known as "cracking," which is used to increase the yield of the inflammable oils, produces an excess of free carbon.

The paraffin petroleum residuums are soft and greasy and are not suitable for road work; they contain a large amount of the paraffin hydrocarbons and paraffin scale (crude paraffin).

The California petroleum residuums resemble asphalt, and if carefully distilled without cracking should contain little or no free carbon. They are suited to road work.

The Texas, or semi-asphaltic, petroleums contain some paraffin hydrocarbons and about 1 per cent of paraffin scale. Residuums from these oils, if containing a relatively small amount of paraffin, can be successfully used.

The tests and required properties of residuum bituminous binders used on the New York State roads in 1911 are given in specifications, page 311.

The following tables give a general idea of the relative characteristics of the crude petroleums and petroleum residuums.

TABLE No. 26. RESULTS OF TESTS OF CRUDE PETROLEUM

Tables from Bulletin No. 34. United States Office of Public Roads

Kinds of Oil	Specific Gravity	Flash Point ° C.	Volatility at 110° C. 7 Hours	Volatility at 160° C. 7 Hours	Volatility at 205° C. 7 Hours	Residue
			%	%	%	%
Pennsylvania, paraffin....	0.801	[a]	47.3	58.0	68.0	[b]32.0
Texas, semi-asphaltic	.904	43	20.0	27.0	49.0	[c]51.0
California, asphaltic	.939	26	....	....	[d]42.7	[e]57.3

[a] *Ordinary temperature* [c] Quick flow [e] Soft maltha; sticky
[b] *Soft* [d] Volatility at 200°, 7 hours.

TABLE 25 A. CIRCULAR NO 97, U. S. OFFICE OF PUBLIC ROADS

Analysis of crude coke-oven tars produced in the United States and Canada.

Serial No.	General Information: Company and location	General Information: Type of Oven	Maximum temperature of firing retorts
5120	Solvay Process Co., Syracuse, N. Y.	Semet-Solvay	1650–1450° C.
5123	Semet Solvay Co. Pennsylvania Steel Co., Steelton, Pa.	"	1050–1450° C.
5124	Semet Solvay Co. National Tube Co., Benwood, W. Va.	"	1050–1450° C.
5137	Semet Solvay Co., Milwaukee Coke & Gas Co., Milwaukee, Wis.	"	1050–1450° C.
5171	Semet Solvay Co. Pennsylvania Steel Co. Lebanon, Pa.	"	1050–1450° C.
5125	By Products Coke Corporation, South Chicago, Ill.	"	1050–1450° C.
5128	Semet Solvay Co., Detroit, Mich.	"	1050–1450° C.
5200	Semet Solvay Co., Empire Coke Co. Geneva, N. Y.	"	1050–1450° C.
5189	Semet-Solvay Co., Dunbar Furnace Co., Dunbar, Pa.		1050–1450° C.
5160	Semet Solvay Co., Central Iron & Coal Co., Tuscaloosa, Ala.	"	1250° C.
5074	Philadelphia Suburban Gas & Electric Co. Chester, Pa.	"	1050° C.
5081	Semet Solvay Co., Ensley, Ala.	"	1250° C.
5005	The N. E. Gas & Coke Co. Everett Mass.	Otto Hoffman	1100° C.
5083	Lackawanna Steel Co. Lackawanna Iron & Steel Co. Lebanon, Pa.	"	1000° C. (1800° F.)
5159	Dominion Tar & Chemical Co., Sydney Nova Scotia	"	(*)
5107	Hamilton Otto Coke Co. Hamilton, Ohio	"	1111° C. (2000° F.)
5086	Carnegie Steel Co. South Sharon, Pa.	United Otto	1666° C. (3000° F.)
5078	Maryland Steel Co., Sparrows Point, Md.	"	1333° C. (2400° F.)
5087	Citizens Gas Co., Indianapolis, Ind.	"	1222° C. (2200° F.)
5109	Pittsburg Gas & Coke Co., The United Coke & Gas Co., Glassport, Pa.	"	(*)
5122	Zenith Furnace Co. Duluth, Minn.	"	1222-1277° C. 2200-2300° F.
5188	Illinois Steel Co. Joliet, Ill.	Koppers	1444° C. (2600° F.)
5404	Illinois Steel Co., Indiana Steel Co. Gary, Ind.	"	1100° C.
5108	Camden Coke Co., Camden, N. J.	Otto Hoffman United Otto	1000° C. (1800° F.) 1222° C. (2200° F.)
5127	Cambria Steel Co., Johnstown, Pa.	Otto Hoffman United Otto	1111° C. (2000° F.) 1111° C. (2000° F.)
5089	Lackawanna Steel Co., Buffalo, N. Y.	United Otto Rothberg	1000° C. (1800° F.) 1000° C. (1800° F.)

TABLE 25 A — *Continued*

Answers to Questions			Examination			
Maximum temperature to which coal is brought	Specific gravity of crude tar	Per cent of free carbon in tar	Specific gravity of tar, 25° C.	Per cent of free carbon	Per cent of ash	Per cent soluble in CS_2, including H_2O
950–1150° C.	1. 12–1. 21	3–12	1.195	7.76	0.12	92.12
950–1150° C.	1. 12–1. 21	3–12	1.206	8.77	.07	91.16
950–1150° C.	1. 12–1. 21	3–12	1.176	7.14	.04	92.82
950–1150° C.	1. 12–1. 21	3–12	1.168	6.10	.05	93.85
950–1150° C.	1. 12–1. 21	3–12	1.173	4.71	.06	95.23
950–1150° C.	1. 12–1. 21	3–12	1.191	7.49	.03	92.48
950–1150° C.	1. 12–1. 21	3–12	1.169	6.56	.11	93.33
950–1150° C.	1. 12–1. 21	3–12	1.159	6.07	.08	93.85
950–1150° C.	1. 12–1. 21	3–12	1.181	8.85	.02	91.13
1150° C.	1. 17	5.72	1.159	5.05	.02	94.93
1000° C.	1.16 (20° C.)	—	1.141	3.96	.05	95.99
1150° C.	1.17 (15° C.)	8	1.175	6.90	.06	93.04
[1] 1200° C.	1.17	8–10	1.160	13.94	.00	86.06
1000° C. (1800° F.)	1.10	16–24	1.214	14.05	.13	85.82
(3)	1.170	10–15	1.143	10.81	.05	89.14
1111° C. (2000° F.)	1.14	[6] 16.0	1.160	8.37	.06	91.57
1444° C. (2600° F.)	1.2	7. 09–10.64	1.191	7.89	.03	92.08
1222° C. (2200° F.)	[3] 1.19	[3] 8–10	1.179	8.49	.03	91.48
1222° C. (2200° F.)	1. 14–1. 15	4–5	1.133	5.21	.07	94 72
(3)	(50° F.) 1.207 10° C.	16.59	1.176	10.53	.04	89.43
(3)	(2)	(2)	1.195	12.18	.05	87.77
1388° C (2500° F.)	1. 16–1. 20	12–15	1.171	3.89	.06	96.05
880–950° C.	[4] 1.174 1.169	4.35	1.169	2.73	.04	97.23
833° C. (1500° F.) 1055° C. (1900° F.)	1. 20–1. 30 [5] (1.221)	7–9 [5] (7.3)	1.182	11.30	.06	88.64
[1] 1111° C. (2000° F.) [1] 1111° C. (2000° F.)	1.12	[1] 15	1.211	12.40	.16	87.44
1000° C. (1800° F.) 1000° C. (1800° F.)	1.16	16–24	1.210	16.80	.00	83.20

TABLE 25 A — *Continued*

Serial No.	Company and Location	Examination, Public Roads — Distillation results — Water: % by vol.	% by weight	Light oils up to 110° C.: % by vol.	% by weight
5126	Solvay Process Co., Syracuse, N.Y.	1.0	0.8	[8]0.3	0.3
5123	Semet Solvay Co., Pennsylvania Steel Co Steelton, Pa.	1.0	.8	.4	.3
5124	Semet Solvay Co., National Tube Co Benwood, W Va.	1.1	1.0	1.9	1.5
5137	Semet-Solvay Co., Milwaukee Coke & Gas Co, Milwaukee, Wis.	1.8	1.5	1.4	1.2
5121	Semet-Solvay Co., Pennsylvania Steel Co., Lebanon, Pa.	6	5	1.6	1.5
5125	By-Products Coke Corporation, South Chicago, Ill.	(1)	(2)	.4	.3
5128	Semet-Solvay Co., Detroit Mich	6.9	5.9	[9]2.8	2.3
5200	Semet Solvay Co., Empire Coke Co, Geneva, N Y	4.0	3.4	2.6	2.1
5189	Semet Solvay Co., Dunbar Furnace Co. Dunbar, Pa	2.0	1.7	1.7	1.4
5160	Semet Solvay Co., Central Iron & Coal Co. Tuscaloosa, Ala.	3.2	2.8	2.4	1.9
5074	Philadelphia Suburban Gas & Electric Co. Chester Pa	2.3	2.0	2.3	1.3
5081	Semet Solvay Co., Ensley, Ala	3.3	2.8	[8]1.4	1.0
5095	The New England Gas & Coke Co, Everett Mass	2.2	2.0	2.0	2.3
5083	Lackawanna Steel Co., Lackawanna Iron & Steel Co., Lebanon Pa	5.4	4.4	[8]1.4	1.4
5150	Dominion Tar & Chemical Co. Sydney, Nova Scotia	3.2	2.8	1.9	1.5
5107	Hamilton Otto Coke Co. Hamilton O.	3.4	3.0	3.1	2.5
5086	Carnegie Steel Co, South Sharon Pa	1.0	1.0	[9]1.6	1.1
5078	Maryland Steel Co. Sparrows Point Md				
5087	Citizens Gas Co, Indianapolis Ind	1.6	1.3	1.5	.9
5109	Pittsburg Gas & Coke Co The United Coke & Gas Co Glassport Pa	1.2	1.1	1.1	.9
5172	Zenith Furnace Co, Duluth, Minn	1.1	1.0	1.1	.9
5188	Illinois Steel Co., Joliet, Ill.	3.6	3.0	1.7	1.3
5404	Illinois Steel Co Indiana Steel Co	1.9	1.6	[8]1.7	1.2
	Gary Ind	3.5	3.0	[9]1.3	1.0
5108	Camden Coke Co. Camden N J	2.2	1.9	1.8	1.4
5127	Cambria Steel Co. Johnstown, Pa	10.1	8.5	[8]3.1	2.3
5089	Lackawanna Steel Co., Buffalo, N.Y.	2.7	2.2	[10].5	.3

REFERENCES TO TABLE 25 A

[1] Approximately
[2] No information
[3] Varies with coal Coal with 28 per cent of volatile matter used
[4] With H_2O.
[5] At present
[6] Variable.
[7] Trace.
[8] Trace of solids.
[9] Distillate solid
[10] Distillate, one-fourth solid.
[11] Distillate nine tenths solid.
[12] Distillate three-fourths solid.
[13] Distillate eight ninths solid.
[14] Distillate, one-half solid.

TABLE 25 A—*Continued*

Examination, Office of Public Roads								
Distillation results								
Middle oils, 110°–170 C.		Heavy oils, 170°–270 C.		Heavy oils, 270°–315° C.		Pitch		Serial No.
% by vol.	% by weight	% by vol.	% by weight	% by vol.	% by weight	% by vol.	% by weight	
0.8	0.7	[22] 13.1	11.5	[19] 8.2	7.3	[25] 76.6	79.1	5126
[9] 2.0	1.7	[9] 14.0	12.3	[20] 7.9	6.9	[26] 74.7	77.6	5123
.7	.6	14.9	13.2	[21] 11.9	10.6	[27] 69.5	73.1	5124
.8	.6	[13] 21.1	18.9	[20] 5.5	4.9	[28] 69.4	72.5	5137
.8	.6	[14] 17.5	15.5	[19] 9.4	8.4	[28] 70.1	73.7	5121
[13] 1.1	.9	[15] 23.6	20.7	[9] 9.8	8.9	[27] 65.1	68.9	5125
[5] .4	.3	[11] 14.6	13.0	[6] 6.9	5.7	[28] 68.4	72.0	5128
.6	.5	[10] 17.6	15.5	[22] 11.4	10.4	[27] 63.8	67.7	5200
.2	.2	[16] 20.0	17.8	[21] 6.5	5.7	[28] 69.6	73.1	5189
.3	.3	18.6	16.3	[10] 7.5	6.8	[27] 68.0	71.5	5160
1.2	.8	22.8	19.5	[19] 13.6	12.5	57.8	62.0	5074
.2	.2	[17] 16.5	14.1	[14] 9.3	8.2	[27] 69.3	73.2	5081
.6	.5	23.5	20.4	[17] 15.6	14.4	[27] 55.2	59.7	5095
[9] .1	.1	[11] 13.0	10.9	[21] 9.4	8.1	[25] 70.7	74.6	5083
.6	.5	27.2	24.2	[19] 7.3	6.7	[27] 59.8	63.5	5159
.7	.6	27.9	24.4	[19] 3.8	3.5	[27] 61.1	64.9	5107
[9] .6	.4	[16] 12.1	10.2	[19] 11.0	9.7	[25] 73.7	77.5	5086
.6	.4	[23] 17.2	15.1	[21] 9.6	8.5	[28] 69.7	73.2	5078
1.4	1.3	23.9	21.4	[10] 11.6	10.4	[27] 60.8	64.7	5087
.5	.4	[18] 26.9	23.6	[14] 6.9	6.3	[27] 63.5	67.6	5109
.4	.3	[11] 18.1	15.9	[19] 12.5	11.1	[27] 63.7	67.8	5122
[9] .2	.2	[9] 20.0	18.0	[11] 13.4	12.0	[28] 62.8	66.3	5188
[9] .4	.3	[9] 20.6	18.5	[9] 7.1	6.5	[28] 67.1	70.2	5404
.6	.5	[14] 20.5	18.2	[23] 8.5	7.5	[26] 66.4	70.1	5108
[9] .3	.2	[9] 7.1	6.1	[12] 7.4	6.9	[26] 72.0	74.8	5127
[9] 2.2	1.7	[9] 11.7	9.9	[24] 11.8	10.2	[27] 71.1	75.0	5089

REFERENCES TO TABLE 25 A

[15] Distillate, two-thirds solid.
[16] Distillate, four-fifths solid.
[17] Distillate, seven-eighths solid.
[18] Distillate, one-ninth solid.
[19] Distillate, one-third solid.
[20] Distillate, one-sixth solid.
[21] Distillate, one-fifth solid.
[22] Distillate, two-fifths solid.
[23] Distillate, one-seventh solid.
[24] Distillate, three-fifths solid.
[25] Pitch, soft and sticky.
[26] Pitch, very soft and sticky.
[27] Pitch, hard and brittle.
[28] Pitch, plastic.

RESULTS OF PETROLEUM RESIDUUMS

Kinds of Oil	Specific Gravity	Flash Point ° C.	Volatility at 200° C. 7 Hours	Residue	Solid Paraffin	Fixed Carbon
			%	%	%	%
Pennsylvania, paraffin....	0.920	186	14.2	a85.8	11.0	3.0
Texas, semi-asphaltic	.974	214	6.2	a93.8	1.7	3.5
California, asphaltic	1.006	191	17.3	a82.7	0.0	6.0

a Soft.

The method of testing bituminous materials recommended by the American Society of Civil Engineers is given below:

AMERICAN SOCIETY OF CIVIL ENGINEERS

SPECIAL COMMITTEE ON
BITUMINOUS MATERIALS FOR ROAD CONSTRUCTION

LIST OF ANALYSES AND METHODS OF TESTING BITUMINOUS MATERIALS PROPOSED BY COMMITTEE

JULY, 1909

TARS

Water-Soluble Materials. — Boil gently 2 grams of material with 25 c.c. of distilled water for one hour. Filter and wash with 25 c.c. of boiling water. Evaporate filtrate in weighed dish to dryness and constant weight at 105° C. Weigh residue. Ignite residue and weigh again, giving weight of inorganic matter plus weight of crucible. Weight #2 minus weight #3 gives weight of organic matter.

Specific Gravity. — Use some standard form of pyknometer. Material and distilled water must have a temperature of 25° C.

For semi-solid and solid materials use Sommer's Pyknometer.

Free Carbon. — The free carbon shall be determined by dissolving, for 15 hours, 2 grams of the compound in 100 c.c. of cold carbon bisulphide, filtering the solution through a weighed Gooch crucible, fitted with an asbestos pad, drying to constant weight, and weighing the insoluble residue; then igniting crucible until all carbon is burned off, weighing the residue (ash). The difference between the 2nd and 3rd weights is "Free Carbon." The difference between the 1st and 3rd is ash which should be noted.

Fixed Carbon. — About one gram of the compound is weighed into a platinum crucible $1\frac{1}{8}$ to $1\frac{1}{2}$ inches high. The crucible with the lid on is heated, first gently, and then until no more smoke and flame issues between the crucible and the lid. It is then

ated three and one-half minutes in the full heat of the burner; en cooled and weighed. The crucible lid is then removed and e crucible and contents allowed to remain in the full heat of the irner until the carbon is burned off, and then weighed again. he difference between these two weights is the Fixed Carbon.

Evaporation. — Twenty grams of compound are heated in a flat-bot-med dish, two and one-half inches in diameter and about one inch gh, for a total of five hours in three successive periods of three, one, nd one hours, respectively, in an oven, the interior of which is main-ined at a uniform and constant temperature of 170° C. This oven to be controlled by any thermo regulator, controlling within two grees, and is to have its full temperatuie before the compound is troduced. The dish must be level. Remove dish from oven and ir contents thoroughly for one minute between successive periods.

Penetration of Residue from Evaporation Test. — The penetration iall be measured by a standard machine using 100 grams load and 2 needle. Use a flat-bottomed glass dish seven-eighths of an inch diameter and one and one-half inches in height. Fill flush with p with material and allow same to stand at room temperature for ne-half hour. Immerse in water bath, covering material for one our. Immerse needle to be used for five minutes in same bath. est at once, making three determinations. The recorded penetra-on will be the average value. Temperature 4° C. and 25° C.

NOTE: Residue must be melted at lowest possible temperature nd thoroughly mixed by stirring.

Melting Point of Residue from Evaporation. — The material whose elting point is to be determined, is melted and poured into a mold at will make a one-half inch cube. A #10-gage wire about 6" 8" long is bent at right angles for a length of ¾" at one end and e center of the cube is placed on this end so that one of the diagonals the vertical face of the cube is parallel to the long part of the wire. ake a bottle of a size about 2" in diameter and 4" high and place a ece of white paper in the bottom of it. Pass the long part of the ire through the cork of the bottle so that the lower edge of the cube ill be within one inch of the bottom of the bottle. Also put a ermometer through the cork so that the bulb is opposite the cube. lace the bottle in a water or oil bath and raise the temperature of e bath at a rate of three to six degrees C. a minute. The melting oint of the material is the temperature of the thermometer inside e bottle at the time that the material touches the paper in the ottom of the bottle.

Distillation. —

Up to 105° C.
From 105° to 170° C.
From 170° to 225° C.
From 225° to 270° C.
From 270° to 300° C.

Seven hundred grams of the compound are weighed into a retort . & A. four pints #4521), whose top is fitted with a tee as close as ssible to the retort, and a condenser pipe 24" to 36" long; the per branch of the tee is used for the insertion of a thermometer.

the top of whose bulb is placed immediately below the main outlet of the tee.

Viscosity or Consistency. — Temperatures at which viscosities will be determined, are 100° C. and 25° C.

Penetrometer to be used in accordance with standard method on materials solid at above temperatures. On materials which at the above temperature, the penetrometer cannot be used, the viscosity shall be determined by one of the following instruments:

Engler Viscosimeter.
Lunge Tar Tester.
New York Testing Laboratory Viscosimeter.

COMPOUNDS PREPARED FROM PETROLEUM OR NATURAL ASPHALT PITCHES

Melting Point of Solid Asphalts. — Same method as for residue from evaporation of tars.

Water-Soluble Materials. — Same method as for tars.

Specific Gravity. — Same method as for tars.

Free Carbon. — Same method as for tars.

Material Soluble in Cold Carbon-Tetrachloride. — Same method as for Free Carbon, except carbon-tetrachloride is used as a solvent instead of carbon bisulphide.

Fixed Carbon. — Same method as for tars.

Paraffin. — 100 grams or less of the compound is distilled rapidly in a retort to dry coke.

Five grams of the well-mixed distillate is treated in a two-ounce flask with 25 c.c. Squibbs absolute ether; after mixing thoroughly, 25 c.c. Squibbs absolute alcohol is added and the flask packed closely in a freezing mixture of finely crushed ice and salt for at least 30 minutes. Filter the precipitate quickly by means of a suction pump, using a #575 C. S. & S. 9 c.m. hardened filter paper. Rinse and wash the flask and precipitate (with 1 to 1 Squibbs alcohol and ether mixture cooled to —17° C.) until free from oil (50 c.c. of washing solution is usually sufficient). When sucked dry remove paper, transfer waxy precipitate to small glass dish, evaporate on steam bath, and weigh paraffin remaining on dish.

Calculation. — Weight of paraffin divided by weight of distillate taken and multiplied by per cent of total distillate used from original sample, equals per cent of paraffin.

Evaporation Test #1. — Same method as for tars.

Penetration of Residue from Evaporation Test #1. — Same method as for similar residue of tars.

Melting Point of Residue from Evaporation Test #1. — Same method as for similar residue of tars.

Solubility in 88° Baumé Naphtha. — Two grams of compound are placed in 4 oz. oil sample bottle made up to 100 c.c. with 88° B naphtha, having a boiling point between 40° C. and 55° C., the whole well shaken until compound is broken up. The bottle is then centrifugalized for 10 minutes, 50 c.c. are withdrawn into a weighed flask, the naphtha distilled by a water bath, and the residue weighed.

Another 10 c.c. of the naphtha solution is run over $3\frac{1}{2}''$ Petri glass and allowed to evaporate for 24 hours at room temperature. Note character of residue, *i.e.*, sticky or oily.

Viscosity or Consistency. — Same as for tars.

Evaporation Test #2. — Same method as for tars except oven temperature shall be 205° C.

Penetration of Residue from Evaporation Test #2. — Same method as for tars.

Melting Point of Residue from Evaporation Test #2. — Same method as for tars.

7. Concrete Materials.

Cement.

There are five different classes of cement, Portland, Natural, Pozzolan, Iron Ore, and Magnesia cements. Of these the Portland or Natural is usually specified.

Portland cement is an artificial mixture of carbonate of lime and clay, ground to a fine powder, thoroughly mixed and burned at a high temperature.

Natural cements are made by burning unground argillaceous limestone or magnesian limestone at a low temperature without the addition of other materials to the natural stone.

Portland cements are usually heavier, stronger, slower setting, and more uniform than the natural cements and are generally used for road structures, such as culverts, retaining walls, etc.; natural cements are often used to advantage for concrete paving base and are usually cheaper than the Portlands.

The tests used to determine the value of the cement are for, 1st, Fineness; 2d, Constancy of Volume; 3d, Time of Initial and Final Set; 4th, Tensile Strength; 5th, Chemical Composition; 6th, Specific Gravity.

The methods of making these tests and the standard requirements are given in specifications, page 324.

Sand.

A good concrete sand should be clean, sharp, and not excessively fine. Particles larger than $\frac{1}{8}''$ are not considered as sand. Crusher dust is often used as a substitute for sand and is satisfactory, provided the stone from which it is obtained is clean and of good quality.

Crushed Stone for Concrete.

Any hard clean stone is satisfactory; dirty, rotten, or badly weathered stone should not be used.

For reinforced concrete the size of the stone is usually $\frac{1}{2}''$ to $1''$ in order to facilitate the compacting of the concrete between the reinforcing bars or mesh. For plain concrete a mixed size is used ranging from $\frac{1}{2}''$ to $3\frac{1}{2}''$; a scientifically graded stone reduces the amount of mortar required, but the structures in road work are so small that it does not pay to attempt to reduce the voids in this

manner and the size that is available is used, varying the proportions of mortar to get a dense product.

Gravel for Concrete.

Screened gravel can be used in the same manner as crushed stone; the pebbles, however, must be clean and hard; shale gravel should not be used.

Unscreened gravel is often used for unimportant culvert foundations and paving base. If it is clean, has not a great excess of fine material, and the cement is properly proportioned to the fine material, it is satisfactory and is usually cheaper than crushed stone concrete.

PART II

THE PRACTICE OF THE SURVEY, DESIGN, ESTIMATES, AND CONSTRUCTION

CHAPTER VIII

THE SURVEY

As the survey furnishes the information for the design, it must be carefully made in regard to the essential features. These are alignment, levels and cross-sections, drainage, information concerning foundation soils, available stone supply, available sand, gravel, filler, etc.; direction and amount of traffic, railroad unloading points, the location of possible new sidings, and such topography along the road as will have a bearing on the design. The survey should be made not more than a year before construction starts and during the open season, as a snowfall of any depth makes the work unreliable and only fit for a rough estimate. When contracts based on winter surveys are awarded it is always necessary to take new cross sections to insure a fair estimate of the excavation.

A party of five men is a well-balanced force for surveys of this character.

Force	*Equipment*	*Stationery*
Engineer	Transit	Reports
Instrument man	Level	Pencils
Three helpers	2 100′ steel tapes	Notebook
	3 50′ metallic tapes	U.S. G. S. map.
	3 pickets	
	2 level rods	*Stakes*
	Pocket compass	For preliminary survey
	Hatchet	110 stakes per mile
	Sledge	For construction
	Axe	220 stakes per mile
	Keel	

The Center Line. The placing of the center-line hubs (transit points) requires good judgment and should be done by the chief of the party. In locating them he considers the principles of alignment discussed on page 17. The hubs are placed at tangent intersections and sometimes at the P.C.'s and P.T.'s of curves and are referenced to at least three permanent points

that will not be disturbed during construction. (See sample page of notes, Fig. 43.)

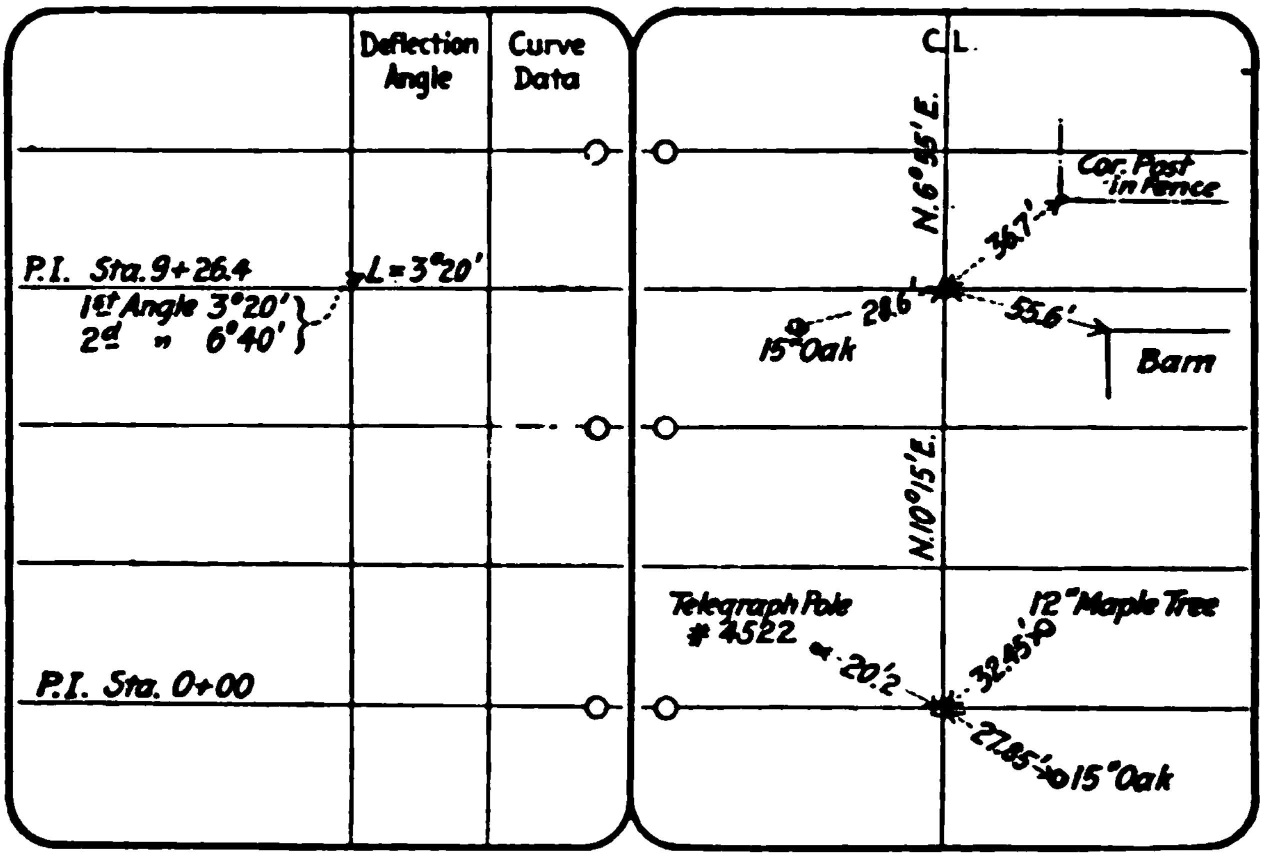


FIG. 43. — Alignment Notes

The deflection angles at the tangent intersections are usually read to the nearest minute, taking a double angle to avoid mistakes; the magnetic bearing of each course is recorded. For all deflection angles over 4° it is good practice to figure and run in on the ground the desired curve. Curves with central angles of less than 4° can be run in with the eye during construction.

The center line is marked at intervals of either fifty or one hundred feet (see cross-section, page 121) in any convenient manner; the alignment of these points should be correct to within 0.2 and the distance along the line to within 0.1 per 100 feet of the length; any attempt to get more accurate stationing is a waste of time. The chaining may be done on the surface of the ground up to a grade of 5 per cent with no objectionable error; beyond that slope, however, the tape should be leveled and plumbed. Steel tapes should be used for chaining the center line and referencing the hubs.

A convenient method of marking the actual center-line stations is to use a nail and piece of flannel; red flannel for the 100′ stations and white flannel for the intermediate 50′ stations, if needed. Where the soil is sandy, or muddy, and these nails would be kicked out or covered, a line of stakes can be set outside of the traveled way on a specific offset from the center line. However, if an offset line is used the chaining of all curves should be done on the center line to insure a correct center-line distance and the stakes placed radially on the desired offset. Railroad

es make good permanent transit points and are easily ed.

t the same time that the line is run it is just as well to paint 100′ station numbers on any convenient place where they be readily seen, as stations marked in this manner make it h easier to sketch in the topography than if marked in chalk takes. Also, if the stations are permanently marked it is er for the construction engineer to pick up the transit points me future time.

party of five men will run from two to four miles of center a day, the speed depending upon the number of curves and th of tangents, if the hubs have been previously placed and enced. If the hubs are placed at the same time the line n, the work is greatly delayed.

wo men can place and reference the transit points at the ent intersections at the rate of from four to ten miles per

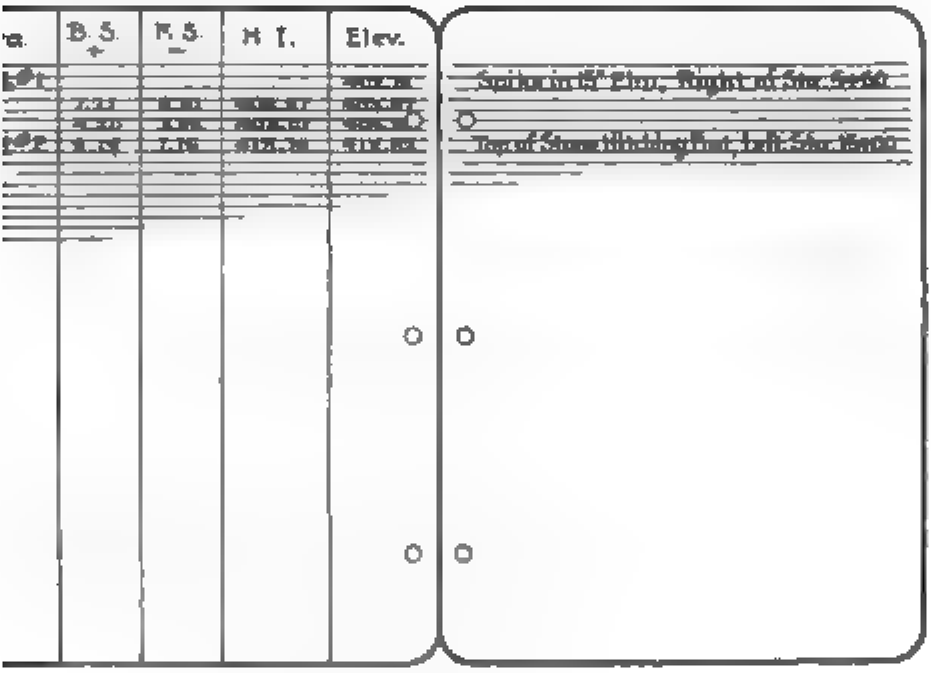


FIG. 44. — Bench Level Notes

evels and Cross-Sections. Bench levels are run in the l manner; the levels will be sufficiently accurate if the rod ad to the nearest 0.01′, for such work any good level and a reading rod graduated to hundredths are satisfactory. ches are established at intervals of 1,000–1,500 feet; they t be substantial, well marked, and so situated as not to be urbed during construction. A small railroad spike in the of a tree, a large boulder, or the water table of a building e good benches.

he bench *levels may* be referred to some local datum in *ral use or to the U. S.* levels, or the datum can be assumed.

In running bench levels it is better to use each bench as a turning point, as side-shot benches may be wrong even if the line of levels is correct.

Cross-sections are taken at either 100′ or 50′ intervals, at all culverts, possible new culvert sites, and any intermediate breaks not shown by the normal interval. Enough sections are taken to show the constantly changing shape of the road.

The distance of the shots from the center line of the road is read to the nearest 1.0′ where the ground has no abrupt change of slope and to the nearest 0.5′ where there is a well-defined abrupt change. The elevations are read to the nearest 0.1′. The sections should extend from fence line to fence line, or in villages from sidewalk to sidewalk, and the position of the pole lines, tree lines, curbs, etc., noted. Engineers differ as to whether the sections should be taken at a normal interval of 50′ or 100′.

Table 27 gives the difference in the computed quantity of earthwork using 50′ and 100′ sections with intermediate sections at well-defined breaks in the grade.

TABLE 27

Name of Road	Length Figured	Character of Road	Excavation 50′ Section	Excavation 100′ Section	Approximate Difference	Per cent of Difference
			Cu. Ft.	Cu. Ft.	Cu. Ft.	
Scottsville Mumford . . .	1 mile	flat	61.444	61.995	550	+ 9/10%
Scottsville Mumford . . .	1 "	hilly	111.109	111.700	600	+ ½ %
Leroy Caledonia	1 "	rolling	57,840	60,560	2700	+ 4⅔ %
*Leroy Caledonia	¾ "	flat	77.841	78,659	800	+ 1 %
Clarence Center	1 "	rolling	73.727	73,048	700	− 1 %
Clarence Center	1 "	flat	38.037	39.415	1400	+ 3 7/10%
Lockport Tonawanda . . .	1 "	flat	59.096	59.470	400	+ 7/10%
*East Henrietta Rochester	1 "	rolling	37,275	36,075	1200	− 3¼ %

The following tabulation shows the variation for shorter ctions of the starred roads.

Name of road and Station to Station	Quantities by 50′ Sections	Quantities by 100′ Sections	Approximate Difference	Per cent of Difference
	Cu. Ft.	Cu. Ft.	Cu. Ft.	
eroy				
aledonia, 80– 90 . . .	19,151	19,525	400	+ 2 %
" 90–100 . . .	21,915	23,415	1500	+ 7 %
" 100–110 . . .	21,555	20,689	900	− 4 %
" 110–120 . . .	15,220	15,030	200	− 1 1/10 %
Total and averages .	77,841	78,659	800	+ 1 %
ast Henrietta				
ochester, 0–19 . . .	14,625	14,300	300	− 2 %
" 32–49 . . .	11,950	11,575	350	− 3 %
" 49–66 . .	10,700	10,200	500	− 5 %
Total and averages .	37,275	36,075	1200	− 3½ %

The question of quantities is not the only factor in determining e interval. Where it is important to fit the local conditions, in a village, or to utilize an old hard foundation, the designer helped by 50′ sections.

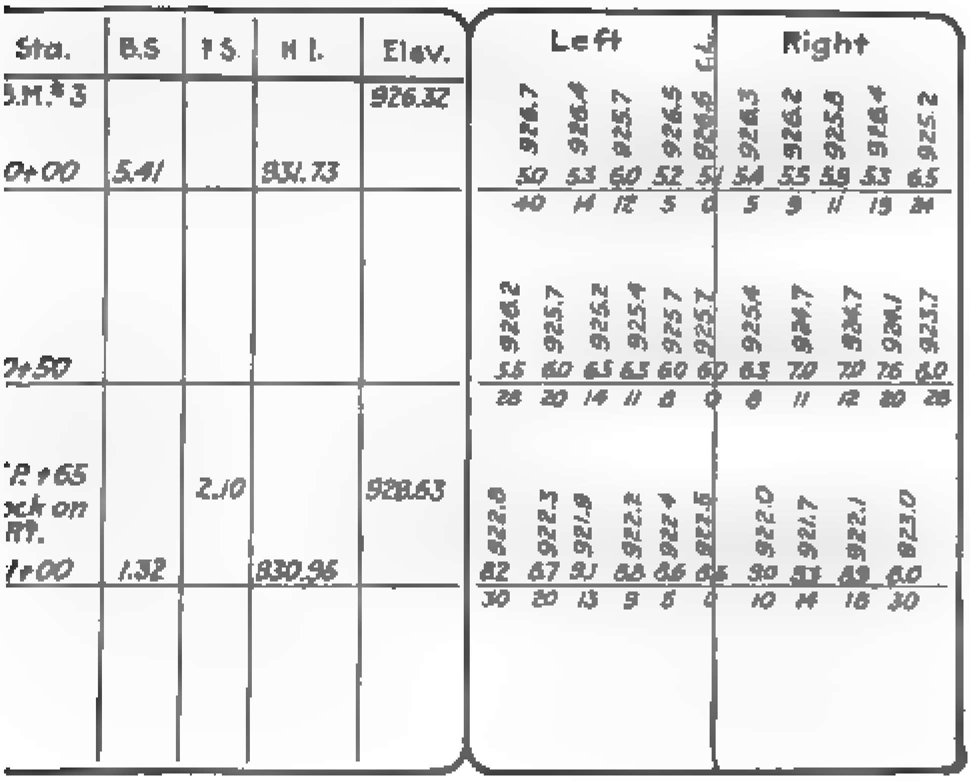


Fig. 45. — Cross-Section Notes

In taking cross-sections the work becomes mechanical, and unless the engineer in charge is unusually alert to all the intermediate changes better results will be obtained by the use of the shorter interval. For these reasons the author believes that a 50′ interval is advisable except on long uniform stretches of road.

A party of three men will run from 4,000 to 7,000 feet of 50′ cross sections per day; a party of four men from 5,000 to 9,000 feet, depending on the country.

DRAINAGE

The drainage notes show the position and size of all the existing culverts; the area of the watersheds draining to them and a

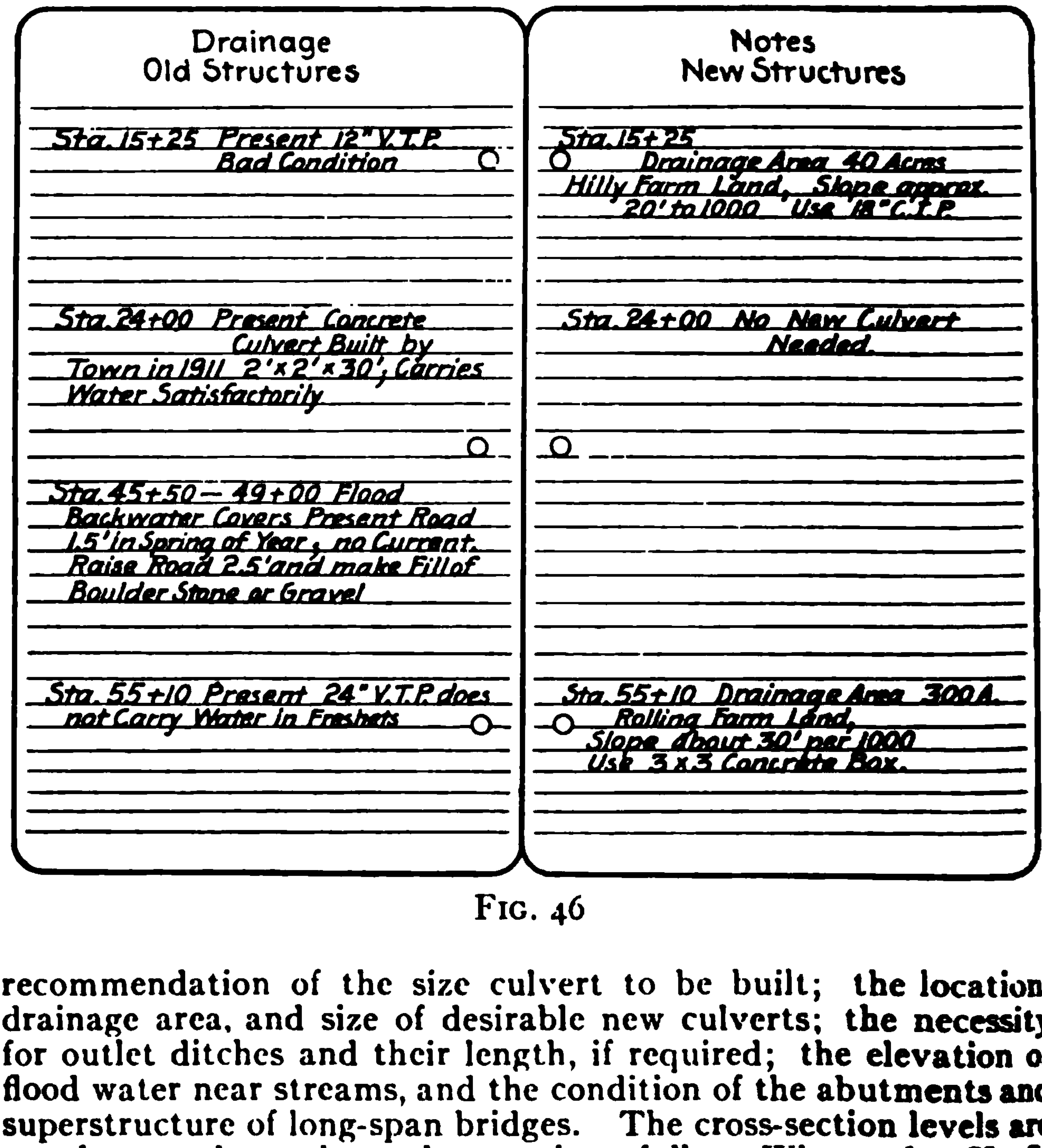


FIG. 46

recommendation of the size culvert to be built; the location, drainage area, and size of desirable new culverts; the necessity for outlet ditches and their length, if required; the elevation of flood water near streams, and the condition of the abutments and superstructure of long-span bridges. The cross-section levels are supplemented to show these points fully. Where the U. S. geological maps are available the areas of watersheds can be *easily determined;* where no such maps have been made the *drainage areas* can be easily mapped with a small 15" plane table

oriented with a magnetic needle; the distances can be paced and the divides determined with a hand level. One inch to 2,000 feet is a convenient scale.

The drainage scheme should be carefully worked out by the Chief of Party, as the possibilities of friction with local people are greater on this part of the design than any other. In the chapter on Drainage this fact was mentioned and designers were cautioned not to use new culverts unless necessary.

TOPOGRAPHY

The topography notes show the features of the adjacent territory that might affect the design. These include the location of buildings, drives, intersecting roads, streams, railroads, poles, trees, sidewalks, crosswalks, and property lines. The names of property owners are recorded.

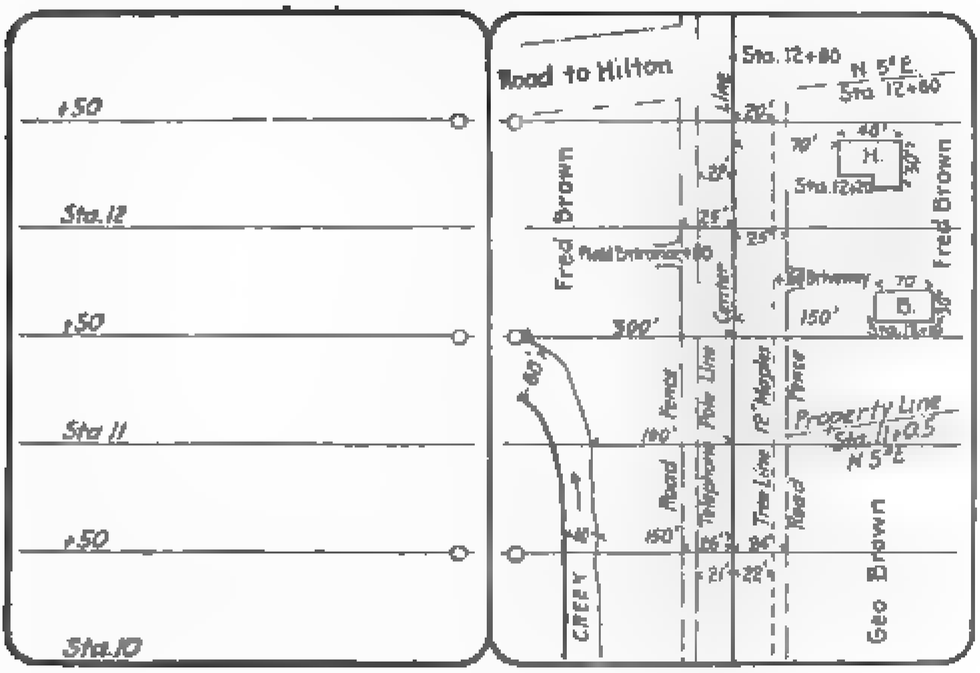


FIG. 47

A simple method of locating these points is to refer them directly to the previously run center line by right-angle offsets; such notes are easily taken and quickly plotted.

In taking the topography the plus stationing along the center line and the offset distances to all points inside of the road fences should be measured by tape to the nearest foot; the distances to and the dimensions of buildings, etc. outside of these limits, can be paced or estimated; the bearings of the property lines can be read near enough with a pocket compass, except for Right of Way surveys which are described on page 127.

The instruments needed for work of this kind are a pocket *compass reading to 2°*, steel picket, and metallic tape.

Two experienced men will take from two miles to four miles of topography a day except in villages, where from one half to a mile is average speed.

DIRECTION AND AMOUNT OF TRAFFIC is determined by inspection and inquiry of the residents along the road.

To illustrate the information required, an extract from the survey report of the Fairport Nine Mile Point Road is given below:

FAIRPORT NINE MILE POINT ROAD TRAFFIC REPORT

Heavy Hauling. The direction of heavy hauling on this road is approximately as follows:

1. Station No. 195 to station 0 towards Fairport.
2. " " 195 " " 400 " Webster.
3. " " 580 " " 400 " "

This divides the road into three sections for the determination of the ruling grades.

The ruling grade for section 1 will be determined by the hills at station 10 and station 48 and probably will be limited to 5 per cent.

The ruling grade for section 2 will be determined by the knolls at stations 267, 285, and 300.

The ruling grade for section 3 will be determined by the hills at stations 445 and 494.

The team traffic is medium heavy station 90 to station 0; light, station 270 to 90; medium, station 270 to 375; heavy, station 375 to 386; very heavy, equivalent to city street, station 386 to 408; medium heavy, station 408 to 450, and light, station 450 to 580. Macadam construction will not be suitable stations 386 to 408.

The automobile pleasure traffic will be largely through traffic and probably fairly heavy.

FOUNDATION SOILS

The notes on soils show the character, width, and depth of the existing surfacing material and the kind of underlying material. This feature of the survey is important, as it governs the thickness of the bottom course, and, to a certain extent, the position of the grade line where an existing solid foundation can be utilized and the thickness of the improved road reduced to a minimum.

Even with a careful soil examination it is impossible to make the design of the foundation definite, as mentioned on page 70, but the quantity of the material that will be needed can be estimated very closely.

The subsoil can be readily examined by driving a 1¼″ or 1″ steel bar to the required depth, which is usually not over 4.0′ to 5.0′ even in cuts, removing the bar and replacing with a ¾″ gas pipe, which is driven a few inches and withdrawn. The core will give a fair idea of the material to be encountered.

Soil Notes			
Sta. to Sta.		Surface Mat.	Sub Surface
0	30	Sand & Gravel	Sand & Gravel
30	31	Clay & Gravel	Clay 1' down
31	36	Clay	Clay
36	40	Gravel 8" deep	Wet Clay
40	41	" 4" "	Clay Loam

Foundation Recommendations
Total Thickness Metalling 6"
" " " 9"
" " " 12"
Underdrain on Rt Stone 15" deep
Fill at this Point " 6" "

FIG. 48

Where rock is encountered the elevation of the outcrop is shown, and if the rock underlies the road for any distance within two or three feet of the surface this depth is determined by driving bars. Sample notes below:

Station	Left	Center Line	Right
62	$\frac{3.5'}{20}$	$\frac{2.5'}{00}$	$\frac{0.5'}{20}$
63	$\frac{1.5'}{25}$	$\frac{1.2'}{00}$	$\frac{1.0'}{22}$

The note $\frac{3.5'}{20}$ means that 20' to the left of the proposed center line of the improvement, the rock is 3.5' below the present surface; from these notes the rock can be readily plotted on the cross-sections. Its character can be determined from adjacent outcrops, or from test pits, if required.

LOCATION AND CHARACTER OF MATERIALS

The selection of materials and the estimate of the construction cost depend on a knowledge of the available materials and their location *relative to* the road.

Unloading Points for Freight. Provided U. S. geological maps are obtainable, the position of sidings may be marked on the sheets. The notes for each siding show its car capacity; whether or not an elevator unloading plant can be erected, and if hand unloading is necessary whether teams can approach from one side or two. They should also show any coal trestles that can be utilized in unloading, and the location and probable cost of any new sidings that will materially reduce the length of the haul. Canal or river unloading points are shown in the same manner.

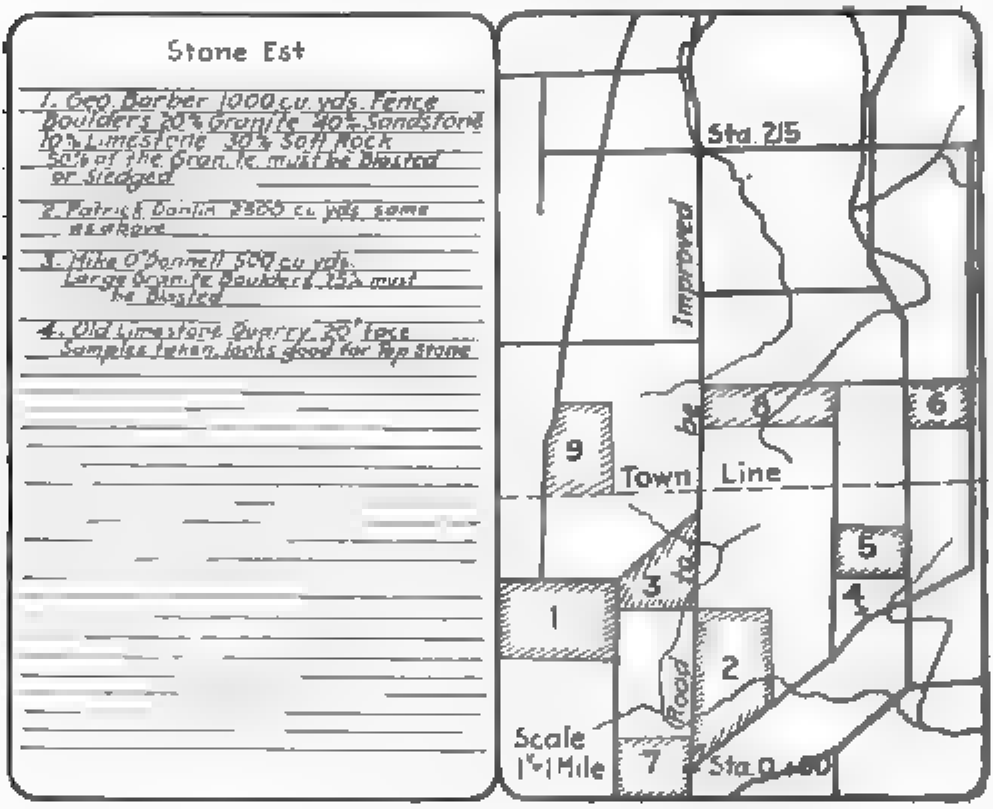


FIG. 40

Sand, Gravel, and Filler Material. The position of sand and gravel pits and filler material are noted with their cost at the pit; if no local material is available the cost f.o.b. at the nearest siding is given.

Stone Supply. Provided imported stone is to be used the work is simplified to determining the rate f.o.b. to the various sidings for the product of the nearest commercial stone-crushing plant that produces a proper grade of stone.

In case local stone is available the location of the quarries or outcrops is shown; the amount of stripping, if any, and the cost of quarry rights. If the estimate will depend upon rock owned by a single person an option is obtained to prevent an exorbitant raise in price

In the case of field or fence stone a careful estimate is made of the number of yards of boulder stone available, the owners'

names, what they will charge for it, the position of the fences or piles relative to the road, or side roads, and if the fences are not abutting on a road or lane the length of haul through fields to the nearest road or lane. As fences are usually a mixture of different kinds of rock, the engineer estimates the percentage of granite, limestone, sandstone, etc., and the percentage that will have to be blasted or sledged in order to be crushed by an ordinary portable crusher. The amount of field stone required per cubic yard of macadam is given in estimates, page 236. If there is a large excess of stone a careful estimate need not be made, only enough data being collected to determine the probable position of the crusher set-ups and the average haul to each set-up. If a sufficient supply is doubtful a close estimate is made as outlined above and options obtained from the various owners.

Samples of the different rocks are tested. (See materials.)

Preliminary surveys of the above description should be made at a speed of from two to four miles per week at a cost of from $35 to $70 per mile, allowing $6 per day for the engineer; $3.50 for the instrument man; $2 per man for three laborers; $1 per day board per man and $4 per day for livery.

Right of Way and diversion line surveys are often needed but are usually not made at this time; if the designer believes that additional land must be acquired or that a diversion line is necessary, he indicates the information desired and the surveys are made.

RIGHT OF WAY SURVEYS

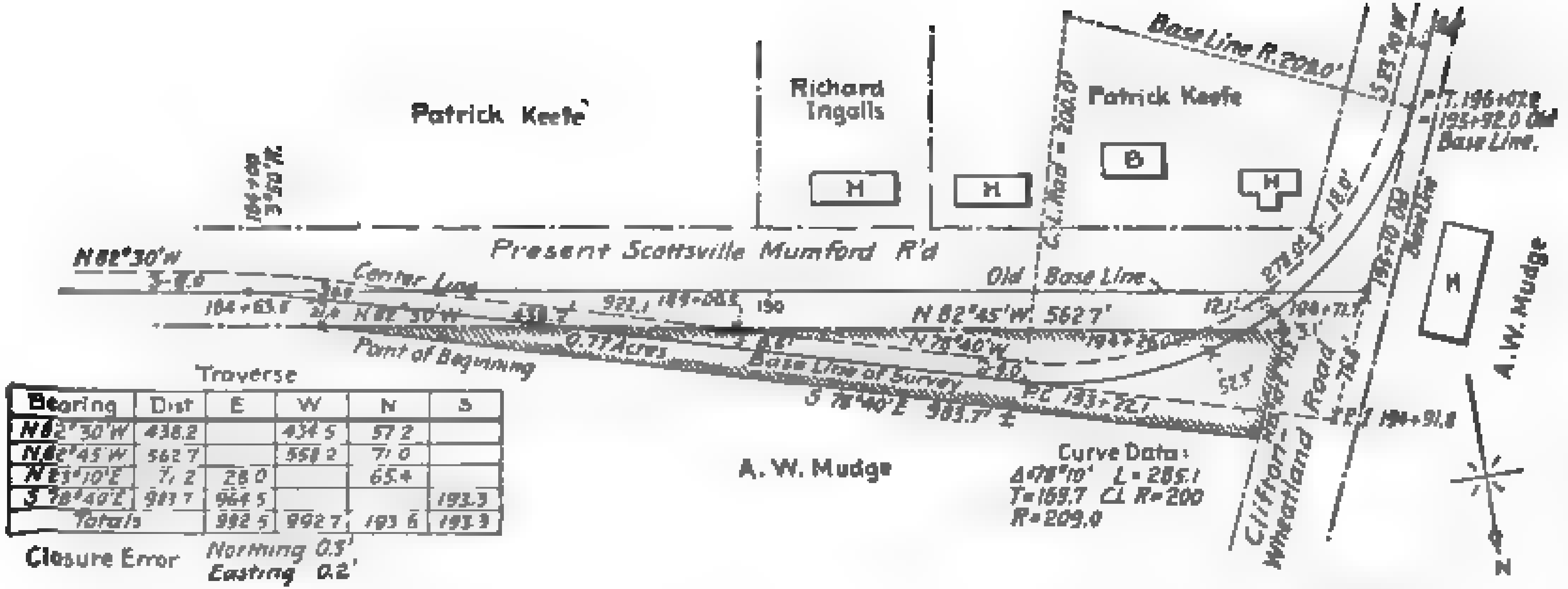
These surveys are used not only to show the amount of land to be acquired but, also, the damage to property from altering the shape of a field, cutting a farm in two, changing the position of a house or barn relative to the road, etc.

The acreage to be taken is shown by an ordinary land survey in which the road lines, property lines, corners, etc., are located in relation to the proposed center line of the improvement, and their lengths and bearings carefully determined. It is often difficult to locate the road boundaries, as town records are carelessly kept and there is a general tendency to encroach on the road. As the amount paid for new Right of Way is rarely settled on an acreage basis, it is customary to take the existing fence lines as the road line unless it is very evident that the fence has been moved. This produces better feeling on the part of the property owner and does not affect the price paid. The lines between adjoining properties are usually well defined.

In cases where an orchard is damaged the position and size of the trees are noted; where a field or farm is cut the whole field is shown, with the shape and acreage of the pieces remaining after the land actually appropriated has been taken out.

As is usually done in all land surveys, the parcel to be bought is traversed and the survey figured for closure error to insure the description against mistakes.

The standard form of map and description of the N. Y. Sta[te] *Department is shown in* the following illustration:



Traverse

Bearing	Dist	E	W	N	S
N82°30'W	438.2		434.5	57.2	
N82°45'W	562.7		558.2	71.0	
N23°10'E	71.2	28.0		65.4	
S78°40'E	983.7	964.5			193.3
Totals		992.5	992.7	193.6	193.3

Closure Error Northing 0.3' Easting 0.2'

FIG. 50. — Land to be Acquired for the Scottsville-Mumford State Highway, Monroe County Route No. 16, Section No. 1, from A. W. Mudge.

All that piece or parcel of land situate in the Town of Wheatland, County of Monroe, State of N.Y., for the Scottsville-Mumford State Highway, as shown on the accompanying map and described as follows:—

Beginning at a point in the northerly boundary of the existing Scottsville-Mumford highway, 21.0 feet northerly, measured at right angles, from station 184+63.5 of the survey base line of the proposed Scottsville-Mumford State Highway (Route No. 16, Section No. 1), and 30.0 feet distant northerly, measured at right angles, from the hereinafter described center line of the said proposed State highway; thence N. 82° 30′ W., along the northerly boundary of the said existing Scottsville-Mumford Highway; 438.2 feet, to a point 8.5 feet distant, southerly, measured at right angles, from station 189+00.5 of the said base line; thence N. 82°45′ W. along the northerly boundary of the said highway, 562.7 feet; to a point 3.1 feet distant northwesterly, measured radially, from station 194+71.7 of the said base line and 12.1 feet distant; measured radially, from the said center line; thence N. 23° 10′ E. along the easterly boundary of the existing Wheatland-Clifton Highway, 71.2 feet to a point 52.3 feet distant northerly, measured radially from station 194+26 of the said base line, thence S. 78° 40′ E. 983.7 ± feet to the point of beginning; being 0.77 acres more or less.

The above mentioned center line is a portion of the center line of the said proposed Scottsville-Mumford State Highway (Route No. 16, Section No. 1) as shown on a map on file in the office of the Clerk of Monroe County, and is described as follows:—

Beginning at a point 9.0 feet distant southerly, measured at right angles, from Station 185+00 of the said base line; thence N. 82° 30′ W. 100 feet; thence N. 78° 40′ W. 922.1 feet; thence curving to the left with a radius 200 feet; 272 ± feet to a point 9.0 feet distant southeasterly, measured radially, from Station 196+07.2 of the said base line (= 195+92.0 old base line) thence S. 23° 10′ W.

[1] HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS

0°		1°		2°		3°	
Hor. Dist	Diff Elev	Hor. Dist.	Diff Elev.	Hor Dist.	Diff Elev	Hor Dist.	Diff. Elev.
100.00	0.00	99.97	1.74	99.88	3.49	99.73	5.23
100.00	0.06	99.97	1.80	99.87	3.55	99.72	5.28
100.00	0.12	99.97	1.86	99.87	3.60	99.71	5.34
100.00	0.17	99.96	1.92	99.87	3.66	99.71	5.40
100.00	0.23	99.96	1.98	99.86	3.72	99.70	5.46
100.00	0.29	99.96	2.04	99.86	3.78	99.69	5.52
100.00	0.35	99.96	2.09	99.85	3.84	99.69	5.57
100.00	0.41	99.95	2.15	99.85	3.90	99.68	5.63
100.00	0.47	99.95	2.21	99.84	3.95	99.68	5.69
100.00	0.52	99.95	2.27	99.84	4.01	99.67	5.75
100.00	0.58	99.95	2.33	99.83	4.07	99.66	5.80
100.00	0.64	99.94	2.38	99.83	4.13	99.66	5.86
100.00	0.70	99.94	2.44	99.82	4.18	99.65	5.92
99.99	0.76	99.94	2.50	99.82	4.24	99.64	5.98
99.99	0.81	99.93	2.56	99.81	4.30	99.63	6.04
99.99	0.87	99.93	2.62	99.81	4.36	99.63	6.09
99.99	0.93	99.93	2.67	99.80	4.42	99.62	6.15
99.99	0.99	99.93	2.73	99.80	4.48	99.62	6.21
99.99	1.05	99.92	2.79	99.79	4.53	99.61	6.27
99.99	1.11	99.92	2.85	99.79	4.59	99.60	6.33
99.99	1.16	99.92	2.91	99.78	4.65	99.59	6.38
99.99	1.22	99.91	2.97	99.78	4.71	99.59	6.44
99.98	1.28	99.91	3.02	99.77	4.76	99.58	6.50
99.98	1.34	99.90	3.08	99.77	4.82	99.57	6.56
99.98	1.40	99.90	3.14	99.76	4.88	99.56	6.61
99.98	1.45	99.90	3.20	99.76	4.94	99.56	6.67
99.98	1.51	99.89	3.26	99.75	4.99	99.55	6.73
99.98	1.57	99.89	3.31	99.74	5.05	99.54	6.78
99.97	1.63	99.89	3.37	99.74	5.11	99.53	6.84
99.97	1.69	99.88	3.43	99.73	5.17	99.52	6.90
99.97	1.74	99.88	3.49	99.73	5.23	99.51	6.96
0.75	0.01	0.75	0.02	0.75	0.03	0.75	0.05
1.00	0.01	1.00	0.03	1.00	0.04	1.00	0.06
1.25	0.02	1.25	0.03	1.25	0.05	1.25	0.08

Theory and Practice of Surveying," by Prof. J. B. Johnson, New Yo
Sons. *We are enabled to use this form through the courtesy of*

Table 28. Horizontal Distances and Elevations from Stadia Readings.—*Continued*

	4°		5°		6°		7°	
Minutes	Hor Dist	Diff Elev	Hor Dist	Diff Elev	Hor Dist.	Diff Elev	Hor. Dist.	Diff Elev
0	99.51	6.96	99.24	8.68	98.91	10.40	98.51	12.10
2	99.51	7.02	99.23	8.74	98.90	10.45	98.50	12.15
4	99.50	7.07	99.22	8.80	98.88	10.51	98.48	12.21
6	99.49	7.13	99.21	8.85	98.87	10.57	98.47	12.26
8	99.48	7.19	99.20	8.91	98.86	10.62	98.46	12.32
10	99.47	7.25	99.19	8.97	98.85	10.68	98.44	12.38
12	99.46	7.30	99.18	9.03	98.83	10.74	98.43	12.43
14	99.46	7.36	99.17	9.08	98.82	10.79	98.41	12.49
16	99.45	7.42	99.16	9.14	98.81	10.85	98.40	12.55
18	99.44	7.48	99.15	9.20	98.80	10.91	98.39	12.60
20	99.43	7.53	99.14	9.25	98.78	10.96	98.37	12.66
22	99.42	7.59	99.13	9.31	98.77	11.02	98.36	12.72
24	99.41	7.65	99.11	9.37	98.76	11.08	98.34	12.77
26	99.40	7.71	99.10	9.43	98.74	11.13	98.33	12.83
28	99.39	7.76	99.09	9.48	98.73	11.19	98.31	12.88
30	99.38	7.82	99.08	9.54	98.72	11.25	98.29	12.94
32	99.38	7.88	99.07	9.60	98.71	11.30	98.28	13.00
34	99.37	7.94	99.06	9.65	98.69	11.36	98.27	13.05
36	99.36	7.99	99.05	9.71	98.68	11.42	98.25	13.11
38	99.35	8.05	99.04	9.77	98.67	11.47	98.24	13.17
40	99.34	8.11	99.03	9.83	98.65	11.53	98.22	13.22
42	99.33	8.17	99.01	9.88	98.64	11.59	98.20	13.28
44	99.32	8.22	99.00	9.94	98.63	11.64	98.19	13.33
46	99.31	8.28	98.99	10.00	98.61	11.70	98.17	13.39
48	99.30	8.34	98.98	10.05	98.60	11.76	98.16	13.45
50	99.29	8.40	98.97	10.11	98.58	11.81	98.14	13.50
52	99.28	8.45	98.96	10.17	98.57	11.87	98.13	13.56
54	99.27	8.51	98.94	10.22	98.56	11.93	98.11	13.61
56	99.26	8.57	98.93	10.28	98.54	11.98	98.10	13.67
58	99.25	8.63	98.92	10.34	98.53	12.04	98.08	13.73
60	99.24	8.68	98.91	10.40	98.51	12.10	98.06	13.78
$c = 0.75$	0.75	0.06	0.75	0.07	0.75	0.08	0.74	0.10
$c = 1.00$	1.00	0.08	0.99	0.09	0.99	0.11	0.99	0.13
$c = 1.25$	1.25	0.10	1.24	0.11	1.24	0.14	1.24	0.16

Table 28. Horizontal Distances and Elevations from Stadia Readings. — *Continued*

	8°		9°		10°		11°	
Minutes	Hor Dist.	Diff. Elev.	Hor Dist	Diff. Elev.	Hor Dist	Diff Elev.	Hor Dist	Diff. Elev
0	98.06	13.78	97.55	15.45	96.98	17.10	96.30	18.73
2	98.05	13.84	97.53	15.51	96.96	17.16	96.34	18.78
4	98.03	13.89	97.52	15.56	96.94	17.21	96.32	18.84
6	98.01	13.95	97.50	15.62	96.92	17.26	96.29	18.89
8	98.00	14.01	97.48	15.67	96.90	17.32	96.27	18.95
10	97.98	14.06	97.46	15.73	96.88	17.37	96.25	19.00
12	97.97	14.12	97.44	15.78	96.86	17.43	96.23	19.05
14	97.95	14.17	97.43	15.84	96.84	17.48	96.21	19.11
16	97.93	14.23	97.41	15.89	96.82	17.54	96.18	19.16
18	97.92	14.28	97.39	15.95	96.80	17.59	96.16	19.21
20	97.90	14.34	97.37	16.00	96.78	17.65	96.14	19.27
22	97.88	14.40	97.35	16.06	96.76	17.70	96.12	19.32
24	97.87	14.45	97.33	16.11	96.74	17.76	96.09	19.38
26	97.85	14.51	97.31	16.17	96.72	17.81	96.07	19.43
28	97.83	14.56	97.29	16.22	96.70	17.86	96.05	19.48
30	97.82	14.62	97.28	16.28	96.68	17.92	96.03	19.54
32	97.80	14.67	97.26	16.33	96.66	17.97	96.00	19.59
34	97.78	14.73	97.24	16.39	96.64	18.03	95.98	19.64
36	97.76	14.79	97.22	16.44	96.62	18.08	95.96	19.70
38	97.75	14.84	97.20	16.50	96.60	18.14	95.93	19.75
40	97.73	14.90	97.18	16.55	96.57	18.19	95.91	19.80
42	97.71	14.95	97.16	16.61	96.55	18.24	95.89	19.86
44	97.69	15.01	97.14	16.66	96.53	18.30	95.86	19.91
46	97.68	15.06	97.12	16.72	96.51	18.35	95.84	19.96
48	97.66	15.12	97.10	16.77	96.49	18.41	95.82	20.02
50	97.64	15.17	97.08	16.83	96.47	18.46	95.79	20.07
52	97.62	15.23	97.06	16.88	96.45	18.51	95.77	20.12
54	97.61	15.28	97.04	16.94	96.42	18.57	95.75	20.18
56	97.59	15.34	97.02	16.99	96.40	18.62	95.72	20.23
58	97.57	15.40	97.00	17.05	96.38	18.68	95.70	20.28
60	97.55	15.45	96.98	17.10	96.36	18.73	95.68	20.34
$c = 0.75$	0.74	0.11	0.74	0.12	0.74	0.14	0.73	0.15
$c = 1.00$	0.99	0.15	0.99	0.16	0.98	0.18	0.98	0.20
$c = 1.25$	1.23	0.18	1.23	0.21	1.23	0.23	1.22	0.25

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	12°		13°		14°		15°	
Minutes	Hor Dist.	Diff. Elev	Hor Dist.	Diff. Elev.	Hor Dist	Diff Elev.	Hor. Dist.	Diff. Elev.
0	95.68	20.34	94.94	21.92	94.15	23.47	93.30	25.00
2	95.65	20.39	94.91	21.97	94.12	23.52	93.27	25.05
4	95.63	20.44	94.89	22.02	94.09	23.58	93.24	25.10
6	95.61	20.50	94.86	22.08	94.07	23.63	93.21	25.15
8	95.58	20.55	94.84	22.13	94.04	23.68	93.18	25.20
10	95.56	20.60	94.81	22.18	94.01	23.73	93.16	25.25
12	95.53	20.66	94.79	22.23	93.98	23.78	93.13	25.30
14	95.51	20.71	94.76	22.28	93.95	23.83	93.10	25.35
16	95.49	20.76	94.73	22.34	93.93	23.88	93.07	25.40
18	95.46	20.81	94.71	22.39	93.90	23.93	93.04	25.45
20	95.44	20.87	94.68	22.44	93.87	23.99	93.01	25.50
22	95.41	20.92	94.66	22.49	93.84	24.04	92.98	25.55
24	95.39	20.97	94.63	22.54	93.81	24.09	92.95	25.60
26	95.36	21.03	94.60	22.60	93.79	24.14	92.92	25.65
28	95.34	21.08	94.58	22.65	93.76	24.19	92.89	25.70
30	95.32	21.13	94.55	22.70	93.73	24.24	92.86	25.75
32	95.29	21.18	94.52	22.75	93.70	24.29	92.83	25.80
34	95.27	21.24	94.50	22.80	93.67	24.34	92.80	25.85
36	95.24	21.29	94.47	22.85	93.65	24.39	92.77	25.90
38	95.22	21.34	94.44	22.91	93.62	24.44	92.74	25.95
40	95.19	21.39	94.42	22.96	93.59	24.49	92.71	26.00
42	95.17	21.45	94.39	23.01	93.56	24.55	92.68	26.05
44	95.14	21.50	94.36	23.06	93.53	24.60	92.65	26.10
46	95.12	21.55	94.34	23.11	93.50	24.65	92.62	26.15
48	95.09	21.60	94.31	23.16	93.47	24.70	92.59	26.20
50	95.07	21.66	94.28	23.22	93.45	24.75	92.56	26.25
52	95.04	21.71	94.26	23.27	93.42	24.80	92.53	26.30
54	95.02	21.76	94.23	23.32	93.39	24.85	92.49	26.35
56	94.99	21.81	94.20	23.37	93.36	24.90	92.46	26.40
58	94.97	21.87	94.17	23.42	93.33	24.95	92.43	26.45
60	94.94	21.92	94.15	23.47	93.30	25.00	92.40	26.50
$c = 0.75$	0.73	0.16	0.73	0.17	0.73	0.19	0.72	0.20
$c = 1.00$	0.98	0.22	0.97	0.23	0.97	0.25	0.96	0.27
$c = 1.25$	1.22	0.27	1.21	0.29	1.21	0.31	1.20	0.34

3. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

16°		17°		18°		19°	
Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
92.40	26.50	91.45	27.96	90.45	29.39	89.40	30.78
92.37	26.55	91.42	28.01	90.42	29.44	89.36	30.83
92.34	26.59	91.39	28.06	90.38	29.48	89.33	30.87
92.31	26.64	91.35	28.10	90.35	29.53	89.29	30.92
92.28	26.69	91.32	28.15	90.31	29.58	89.26	30.97
92.25	26.74	91.29	28.20	90.28	29.62	89.22	31.01
92.22	26.79	91.26	28.25	90.24	29.67	89.18	31.06
92.19	26.84	91.22	28.30	90.21	29.72	89.15	31.10
92.15	26.89	91.19	28.34	90.18	29.76	89.11	31.15
92.12	26.94	91.16	28.39	90.14	29.81	89.08	31.19
92.09	26.99	91.12	28.44	90.11	29.86	89.04	31.24
92.06	27.04	91.09	28.49	90.07	29.90	89.00	31.28
92.03	27.09	91.06	28.54	90.04	29.95	88.96	31.33
92.00	27.13	91.02	28.58	90.00	30.00	88.93	31.38
91.97	27.18	90.99	28.63	89.97	30.04	88.89	31.42
91.93	27.23	90.96	28.68	89.93	30.09	88.86	31.47
91.90	27.28	90.92	28.73	89.90	30.14	88.82	31.51
91.87	27.33	90.89	28.77	89.86	30.19	88.78	31.56
91.84	27.38	90.86	28.82	89.83	30.23	88.75	31.60
91.81	27.43	90.82	28.87	89.79	30.28	88.71	31.65
91.77	27.48	90.79	28.92	89.76	30.32	88.67	31.69
91.74	27.52	90.76	28.96	89.72	30.37	88.64	31.74
91.71	27.57	90.72	29.01	89.69	30.41	88.60	31.78
91.68	27.62	90.69	29.06	89.65	30.46	88.56	31.83
91.65	27.67	90.66	29.11	89.61	30.51	88.53	31.87
91.61	27.72	90.62	29.15	89.58	30.55	88.49	31.92
91.58	27.77	90.59	29.20	89.54	30.60	88.45	31.96
91.55	27.81	90.55	29.25	89.51	30.65	88.41	32.01
91.52	27.86	90.52	29.30	89.47	30.69	88.38	32.05
91.48	27.91	90.48	29.34	89.44	30.74	88.34	32.09
91.45	27.96	90.45	29.39	89.40	30.78	88.30	32.14
0.72	0.21	0.72	0.23	0.71	0.24	0.71	0.25
0.96	0.28	0.95	0.30	0.95	0.32	0.94	0.33
1.20	0.35	1.19	0.38	1.19	0.40	1.18	0.42

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

Minutes.	20° Hor Dist.	20° Diff Elev	21° Hor Dist.	21° Diff Elev	22° Hor Dist.	22° Diff Elev	23° Hor Dist.	23° Diff Elev
0	88.30	32.14	87.16	33.46	85.97	34.73	84.73	35.97
2	88.26	32.18	87.12	33.50	85.93	34.77	84.69	36.01
4	88.23	32.23	87.08	33.54	85.89	34.82	84.65	36.05
6	88.19	32.27	87.04	33.59	85.85	34.86	84.61	36.09
8	88.15	32.32	87.00	33.63	85.80	34.90	84.57	36.13
10	88.11	32.36	86.96	33.67	85.76	34.94	84.52	36.17
12	88.08	32.41	86.92	33.72	85.72	34.98	84.48	36.21
14	88.04	32.45	86.88	33.76	85.68	35.02	84.44	36.25
16	88.00	32.49	86.84	33.80	85.64	35.07	84.40	36.29
18	87.96	32.54	86.80	33.84	85.60	35.11	84.35	36.33
20	87.93	32.58	86.77	33.89	85.56	35.15	84.31	36.37
22	87.89	32.63	86.73	33.93	85.52	35.19	84.27	36.41
24	87.85	32.67	86.69	33.97	85.48	35.23	84.23	36.45
26	87.81	32.72	86.65	34.01	85.44	35.27	84.18	36.49
28	87.77	32.76	86.61	34.06	85.40	35.31	84.14	36.53
30	87.74	32.80	86.57	34.10	85.36	35.36	84.10	36.57
32	87.70	32.85	86.53	34.14	85.31	35.40	84.06	36.61
34	87.66	32.89	86.49	34.18	85.27	35.44	84.01	36.65
36	87.62	32.93	86.45	34.23	85.23	35.48	83.97	36.69
38	87.58	32.98	86.41	34.27	85.19	35.52	83.93	36.73
40	87.54	33.02	86.37	34.31	85.15	35.56	83.89	36.77
42	87.51	33.07	86.33	34.35	85.11	35.60	83.84	36.80
44	87.47	33.11	86.29	34.40	85.07	35.64	83.80	36.84
46	87.43	33.15	86.25	34.44	85.02	35.68	83.76	36.88
48	87.39	33.20	86.21	34.48	84.98	35.72	83.72	36.92
50	87.35	33.24	86.17	34.52	84.94	35.76	83.67	36.96
52	87.31	33.28	86.13	34.57	84.90	35.80	83.63	37.00
54	87.27	33.33	86.09	34.61	84.86	35.85	83.59	37.04
56	87.24	33.37	86.05	34.65	84.82	35.89	83.54	37.08
58	87.20	33.41	86.01	34.69	84.77	35.93	83.50	37.12
60	87.16	33.46	85.97	34.73	84.73	35.97	83.46	37.16
$c = 0.75$	0.70	0.26	0.70	0.27	0.69	0.29	0.69	0.30
$c = 1.00$	0.94	0.35	0.93	0.37	0.92	0.38	0.92	0.40
$c = 1.25$	1.17	0.44	1.16	0.46	1.15	0.48	1.15	0.50

…e 28. Horizontal Distances and Elevations from Stadia Readings. — *Continued*

	24°		25°		26°		27°	
…nutes	Hor Dist.	Diff Elev.	Hor. Dist.	[illegible] Elev	Hor Dist	Diff Elev.	Hor Dist.	Diff Elev
	83.46	37.16	82.14	38.30	80.78	39.40	79.39	40.45
	83.41	37.20	82.09	38.34	80.74	39.44	79.34	40.49
	83.37	37.23	82.05	38.38	80.69	39.47	79.30	40.52
	83.33	37.27	82.01	38.41	80.65	39.51	79.25	40.55
	83.28	37.31	81.96	38.45	80.60	39.54	79.20	40.59
	83.24	37.35	81.92	38.49	80.55	39.58	79.15	40.62
	83.20	37.39	81.87	38.53	80.51	39.61	79.11	40.66
	83.15	37.43	81.83	38.56	80.46	39.65	79.06	40.69
	83.11	37.47	81.78	38.60	80.41	39.69	79.01	40.72
	83.07	37.51	81.74	38.64	80.37	39.72	78.96	40.76
	83.02	37.54	81.69	38.67	80.32	39.76	78.92	40.79
	82.98	37.58	81.65	38.71	80.28	39.79	78.87	40.82
	82.93	37.62	81.60	38.75	80.23	39.83	78.82	40.86
	82.89	37.66	81.56	38.78	80.18	39.86	78.77	40.89
	82.85	37.70	81.51	38.82	80.14	39.90	78.73	40.92
	82.80	37.74	81.47	38.86	80.09	39.93	78.68	40.96
	82.76	37.77	81.42	38.89	80.04	39.97	78.63	40.99
	82.72	37.81	81.38	38.93	80.00	40.00	78.58	41.02
	82.67	37.85	81.33	38.97	79.95	40.04	78.54	41.06
	82.63	37.89	81.28	39.00	79.90	40.07	78.49	41.09
	82.58	37.93	81.24	39.04	79.86	40.11	78.44	41.12
	82.54	37.96	81.19	39.08	79.81	40.14	78.39	41.16
	82.49	38.00	81.15	39.11	79.76	40.18	78.34	41.19
	82.45	38.04	81.10	39.15	79.72	40.21	78.30	41.22
	82.41	38.08	81.06	39.18	79.67	40.24	78.25	41.26
	82.36	38.11	81.01	39.22	79.62	40.28	78.20	41.29
	82.32	38.15	80.97	39.26	79.58	40.31	78.15	41.32
	82.27	38.19	80.92	39.29	79.53	40.35	78.10	41.35
	82.23	38.23	80.87	39.33	79.48	40.38	78.06	41.39
	82.18	38.26	80.83	39.36	79.44	40.42	78.01	41.42
	82.14	38.30	80.78	39.40	79.39	40.45	77.96	41.45
0.75	0.68	0.31	0.68	0.32	0.67	0.33	0.66	0.35
1.00	0.91	0.41	0.90	0.43	0.89	0.45	0.89	0.46
1.25	1.14	0.52	1.13	0.54	1.12	0.56	1.11	0.58

TABLE 28. HORIZONTAL DISTANCES AND ELEVATIONS FROM STADIA READINGS. — *Continued*

	28°		29°		30°	
Minutes	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.	Hor. Dist.	Diff. Elev.
0	77.96	41.45	76.50	42.40	75.00	43.30
2	77.91	41.48	76.45	42.43	74.95	43.33
4	77.86	41.52	76.40	42.46	74.90	43.36
6	77.81	41.55	76.35	42.49	74.85	43.39
8	77.77	41.58	76.30	42.53	74.80	43.42
10	77.72	41.61	76.25	42.56	74.75	43.45
12	77.67	41.65	76.20	42.59	74.70	43.47
14	77.62	41.68	76.15	42.62	74.65	43.50
16	77.57	41.71	76.10	42.65	74.60	43.53
18	77.52	41.74	76.05	42.68	74.55	43.56
20	77.48	41.77	76.00	42.71	74.49	43.59
22	77.42	41.81	75.95	42.74	74.44	43.62
24	77.38	41.84	75.90	42.77	74.39	43.65
26	77.33	41.87	75.85	42.80	74.34	43.67
28	77.28	41.90	75.80	42.83	74.29	43.70
30	77.23	41.93	75.75	42.86	74.24	43.73
32	77.18	41.97	75.70	42.89	74.19	43.76
34	77.13	42.00	75.65	42.92	74.14	43.79
36	77.09	42.03	75.60	42.95	74.09	43.82
38	77.04	42.06	75.55	42.98	74.04	43.84
40	76.99	42.09	75.50	43.01	73.99	43.87
42	76.94	42.12	75.45	43.04	73.93	43.90
44	76.89	42.15	75.40	43.07	73.88	43.93
46	76.84	42.19	75.35	43.10	73.83	43.95
48	76.79	42.22	75.30	43.13	73.78	43.98
50	76.74	42.25	75.25	43.16	73.73	44.01
52	76.69	42.28	75.20	43.18	73.68	44.04
54	76.64	42.31	75.15	43.21	73.63	44.07
56	76.59	42.34	75.10	43.24	73.58	44.09
58	76.55	42.37	75.05	43.27	73.52	44.12
60	76.50	42.40	75.00	43.30	73.47	44.15
c = 0.75 ..	0.66	0.36	0.65	0.37	0.65	0.38
c = 1.00 ..	0.88	0.48	0.87	0.49	0.86	0.51
c = 1.25 ..	1.10	0.60	1.09	0.62	1.08	0.64

version Line Surveys. Where there is no doubt as to the e to be adopted, or the alignment to be used, the location ade directly in the field and the center line is run and the sections taken in the same manner as for a preliminary ey. If, however, the country is badly cut up and it is diffi- to make a field location direct, a transit stadia survey is e covering the territory that will include all the possible ions and from the resulting contour map the different loca- are projected and approximate estimates figured. The ted line is then run in the field, cross sections taken in the manner and an accurate estimate made. This method is so seldom that the author does not feel justified in giving e to the theory of stadia measurements or the methods of a surveys. If the reader is not familiar with this class of he is referred to the standard works on surveying.

convenient scale for a contour map for the projection work ioned above is 1″ = 20′ with a contour interval of 1′ to 5′, nding on the country. Table 28 is useful for reducing stadia . For a small number of shots this table and a slide rule answer the purpose; for any extended amount of work a a reduction diagram or Noble & Casgrain's tables are recom- ed.

the stadia work is well done very satisfactory projections e made.

ADJUSTMENT OF INSTRUMENTS

'e Level. *To make the line of collimation parallel to the ope rings.* Level the instrument roughly. Loosen the Y os so the telescope can turn freely in them; clamp the hori- l motion and by means of the leveling screws and tangent n bring the intersection of the cross hairs on some well- ed point. Then, without lifting from the Ys, turn the ope over 180° watching to see if the cross wires remain on oint during the operation; if they do the adjustment is t; if they do not, correct ½ the apparent error for both al and horizontal wires by means of the cross hair ring, ting screws, and repeat until the wires remain on the point complete revolution.

make the longitudinal axis of the level bubble parallel to the plane ine of collimation. Level the machine over either pair of level- rews; unclamp the Ys; rotate the telescope in the Ys until ubble tube is on one side of the bar. If the bubble remains e center the adjustment is correct. If it runs from the e bring it to its correct position by means of the sidewise ting screw at one end of the bubble case.

make the bubble parallel to the rings and line of collimation. the machine; unclamp the Ys; lift the telescope carefully the Ys and reverse end for end; if the bubble runs to the after the telescope has been reversed the adjustment is t; if not, correct ½ the error by means of the adjusting

nuts on the bubble case and ½ the error with the leveling screws and repeat the test until the bubble remains in the center.

To adjust the Ys so the level bubble will be at right angles to the axis of the instrument. Level the machine approximately over both sets of screws; level carefully over one set; rotate on the spindle 180°; if the bubble remains in the center the adjustment is correct; if not, correct ½ the error by means of the adjusting nuts on the Ys and ½ by the leveling screws. Repeat until the bubble remains in the center when reversed over either pair of leveling screws.

To test the horizontal wire. Be sure that the pin in the Y clamp is in the notch of the telescope ring to keep the telescope from rotating; level the machine and compare the horizontal wire with any level line; if the wire is not level loosen the cross wire ring and turn to the correct position. Adjust again for collimation and the level adjustments are complete.

Dumpy Level.

To make the bubble perpendicular to the axis of the instrument. Level the machine roughly over both sets of leveling screws and carefully over one set; rotate on the pinion 180°; if the bubble stays in the center the adjustment is correct; if not, correct ½ the error by means of the bubble adjusting nut and ½ by the leveling screws, and repeat until correct.

To make the horizontal line of collimation parallel to the level bubble. Level the machine; drive a stake about 150′ or 200′ from the instrument and set the level rod target by the horizontal wire; rotate the instrument 180° and set another stake at the same distance from the machine as the first one; drive it until a rod reading taken on it is the same as the reading on the first stake. These stakes will then be level even though the machine is out of adjustment. Then set the level up near one of the stakes; level carefully and take rod readings on both; if these readings are the same the level is in adjustment; if not, correct the position of the horizontal wire by means of the cross wire ring screws until the readings on both stakes are the same.

Test the horizontal wire on a level line in the same manner as for the Y level.

Transit.

Plate levels. Level the machine with each plate level bubble parallel to one set of leveling screws; rotate on the spindle 180°; if the bubbles remain in the center the adjustment is correct; if not, correct ½ the error with the bubble adjusting screws and ½ with the leveling screws. Repeat until correct.

Line of collimation, ordinary distances. Level the machine; clamp the horizontal motion; with the slow motion screw, set the vertical cross wire on some well-defined point 500 or 600 feet away; transit the telescope and set a mark the same dis-

tance in the opposite direction; then rotate the machine on the spindle, set on the first mark and transit the telescope; if the vertical wire strikes the second point the adjustment is correct; if not, correct ¼ the error by means of cross wire ring adjusting screws and repeat until correct.

To make the standards the same height. Level the machine carefully; set the vertical wire on some well-defined point as high as can be seen; bring the telescope down and set a point; rotate the machine 180°; transit the telescope set on the low point and raise the telescope; if the wire bisects the original high point the adjustment is correct; if not, correct ½ the error by means of the standard adjusting screw.

Test the vertical wire by means of a plumb line to see that it is vertical; if not, loosen the cross hair ring and turn to the correct position; test again for collimation.

If the transit is to be used as a level make the level bubble parallel to the horizontal wire by the two-peg method in the same manner as described for the Dumpy level.

EXPLANATION OF CURVE TABLES AND DEVELOPMENT OF CURVE FORMULAE

Curves for roadwork need not be as carefully worked out as in railroad surveying. Except for long curves the external is usually measured and the curve run in by the eye, and for this reason many of the tables given in the railway field manuals are omitted and those used are tabulated in a different form.

Table No. 29, Radii of curves. The curve radii are computed on a basis of 5,730 feet as the radius of a one-degree curve and are inversely proportional to the degree of curvature; they are tabulated to the nearest 0.1′. The usual columns showing logarithm of radius, tangent offset and middle ordinate are replaced by the deflection angle per foot of arc, per 25′ of arc, and per 50′ of arc, which saves considerable time in the computation of deflections. These values are tabulated only for even degree, twenty-minute, thirty-minute, and forty-minute curves, as there is always sufficient leeway both in the external and tangent to select a suitable curve from this list.

Table No. 30, Functions of 1° curve. Column 1 gives the central angle Δ for every 10 minutes from 0° to 4°, every minute 4° to 100°, and every 10 minutes 100° to 120°.

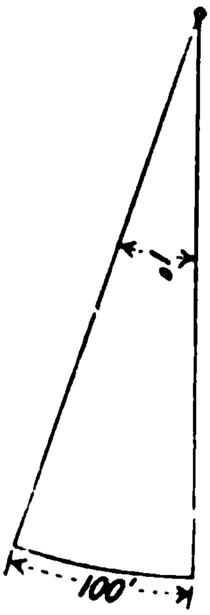


FIG. 51

Column 2 gives the same central angle as in column 1 expressed in decimals of a degree. This simplifies figuring the curve length.

Columns 3 and 4 give the tangent and external for the central angles of column 1 to the nearest 0.1′. By the use of the chord lengths recommended at the top of each page of this table no *correction need be* made for tangent length or external distance

of any desired curve, figured by dividing the value given in the table by the degree of curvature required.

The error that is introduced by the use of these chords is less than 0.1′ per 100′, which is the allowable limit of error in chaining center line.

For the convenience of readers not familiar with the theory of curves and the computation of curve notes, the following brief demonstration is made:

RADII OF CURVES AND DEGREE OF CURVATURE

A one-degree curve is defined as a curve having such a radius that 100 feet of arc will subtend a one-degree central angle.

There are 360° of central angle for a complete circle. The circumference of a circle is expressed by the formula $2\pi R$. Therefore the radius of a one-degree curve is determined by the formulæ

$$2\pi R = 360 \times 100$$

$$R = \frac{36000}{2\pi} = \frac{36000}{2(3.14159)} = 5729.6 \text{ feet} \quad . \quad . \quad . \quad (1)$$

TABLE 29. RADII AND DEFLECTIONS

Figured on a basis of R = 5730′ for a 1° curve.

Degree of Curve	Radius of Curve	Deflection per foot of Arc	Deflection per 25′ of Arc		Deflection per 50′ of Arc	
	Feet	Minutes	Deg.	Minutes	Deg.	Minutes
0° 30′ . .	11,460.0	00.15	—	—	0	07.5
0° 40′ . .	8,595.0	00.2	—	—	0	10.0
0° 50′ . .	6,876.0	00.25	—	—	0	12.5
1° 00′ . .	5,730.0	00.3	—	—	0	15.0
1° 20′ . .	4,297.5	00.4	—	—	0	20.0
1° 30′ . .	3,820.0	00.45	—	—	0	22.5
1° 40′ . .	3,438.0	00.5	—	—	0	25.0
2° 00′ .	2,865.0	00.6	—	—	0	30.0
2° 20′ .	2,455.7	00.7	—	—	0	35.0
2° 30′ . .	2,292.0	00.75	—	—	0	37.5
2° 40′ . .	2,148.8	00.8	—	—	0	40.0
3° 00′ . .	1,910.0	00.9	—	—	0	45.0

TABLE 29. — *Continued*

Degree of Curve	Radius of Curve	Deflection per foot of Arc	Deflection per 25' of Arc		Deflection per 50' of Arc	
	Feet	Minutes	Deg.	Minutes	Deg.	Minutes
3° 20'	1,719.0	01.0	—	—	0	50.0
3° 30'	1,637.1	01.05	—	—	0	52.5
3° 40'	1,562.7	01.1	—	—	0	55.0
4° 00'	1,432.5	01.2	—	—	1	00.0
4° 20'	1,322.3	01.3	—	—	1	05.0
4° 30'	1,273.3	01.35	—	—	1	07.5
4° 40'	1,227.9	01.4	—	—	1	10.0
5° 00'	1,146.0	01.5	—	—	1	15.0
5° 30'	1,041.8	01.65	—	—	1	22.5
6° 00'	955.0	01.8	—	—	1	30.0
6° 30'	881.5	01.95	—	—	1	37.5
7° 00'	818.6	02.1	—	—	1	45.0
7° 30'	764.0	02.25	—	—	1	52.5
8° 00'	716.3	02.4	—	—	2	00.0
8° 30'	674.1	02.55	—	—	2	07.5
9° 00'	636.6	02.7	—	—	2	15.0
9° 30'	603.2	02.85	—	—	2	22.5
10° 00'	573.0	03.0	—	—	2	30.0
10° 30'	545.7	03.15	—	—	2	37.5
11° 00'	520.9	03.3	—	—	2	45.0
11° 30'	498.3	03.45	—	—	2	52.5
12° 00'	477.5	03.6	—	—	3	00.0
12° 30'	458.4	03.75	—	—	3	07.5
13° 00'	440.8	03.9	—	—	3	15.0
13° 30'	424.4	04.05	—	—	3	22.5
14° 00'	409.3	04.2	—	—	3	30.0
14° 30'	395.2	04.35	—	—	3	37.5
15° 00'	382.0	04.5	—	—	3	45.0
15° 30'	369.6	04.65	—	—	3	52.5
16° 00'	358.1	04.8	2	00.0	4	00.0
16° 30'	347.3	04.95	2	03.8	4	07.5
17° 00'	337.0	05.1	2	07.5	4	15.0
17° 30'	327.4	05.25	2	11.2	4	22.5
18° 00'	318.3	05.4	2	15.0	4	30.0
18° 30'	309.7	05.55	2	18.7	4	37.5

TABLE 29. — *Continued*

Degrees of Curve	Radius of Curve	Deflection per ft. of Arc	Deflection per 25' of Arc		Deflection p 50' of Arc	
		Minutes	Degree	Minutes		
19° 00'	301.6	05.7	2	22.5		
19° 30'	293.8	05.85	2	26.2		
20° 00'	286.5	06.0	2	30.0		
20° 30'	279.5	06.15	2	33.7		
21° 00'	272.9	06.30	2	37.5		
21° 30'	266.5	06.45	2	41.2		
22° 00'	260.5	06.6	2	45.0		
22° 30'	254.7	06.75	2	48.7		
23° 00'	249.1	06.9	2	52.5		
23° 30'	243.8	07.05	2	56.2		
24° 00'	238.8	07.2	3	00.0		
24° 30'	233.9	07.35	3	03.7		
25° 00'	229.2	07.5	3	07.5		
26° 00'	220.4	07.8	3	15.0		
27° 00'	212.2	08.1	3	22.5		
28° 00'	204.6	08.4	3	30.0		
29° 00'	197.6	08.7	3	37.5		
30° 00'	191.0	09.0	3	45.0	Deflection p 10' of Arc	
31° 00'	184.8	09.3	3	52.5	1°	36
32° 00'	179.1	09.6	4	00.0	1°	39
33° 00'	173.6	09.9	—	—	1°	[illegible]
34° 00'	168.5	10.2		—	1°	45
35° 00'	163.7	10.5	—	—	1°	45
36° 00'	159.2	10.8	—	—	1°	48
37° 00'	154.9	11.1	—	—	1°	51
38° 00'	150.8	11.4	—	—	1°	54
39° 00'	146.9	11.7	—	—	1°	57
40° 00'	143.2	12.0	—	—	2°	00
42° 00'	136.4	12.6	—	—	2°	06'
44° 00'	130.2	13.2	—	—	2°	12'
46° 00'	124.6	13.8	—	—	2°	18'
48° 00'	119.4	14.4	—	—	2°	24'
50° 00'	114.6	15.0	—	—	2°	30'
52° 00'	110.2	15.6	—	—	2°	36'
54° 00'	106.1	16.2	—	—	2°	42'
56° 00'	102.3	16.8	—	—	2°	48'

For all practical purposes the value of 5,730 can be used.

In the same manner a two-degree curve is one having such a radius that 100 feet of arc will subtend two degrees of central angle, and its radius is

$$2\pi R = \frac{360}{2} \times 100$$

$$R = \frac{18000}{2\pi}$$

or ½ of the radius of a one-degree curve.

The radius of a three-degree curve will be ⅓ of 5,730.

The radius of a four-degree curve will be ¼ of 5,730.

The formula for the radius of any degree of curve is therefore

$$R = \frac{5{,}730}{D.} \qquad (2)$$

The degree of curvature for any specified radius is therefore

$$D = \frac{5{,}730}{R.} \qquad (3)$$

In general the degree of curvature is expressed by the central angle subtended by 100 feet of arc, and the radius for that degree of curve is found by dividing 5,730 feet, the radius of a one-degree curve, by the degree of curve desired expressed in degrees and decimals of a degree. That is, if the radius of a 3° 30′ curve is wanted, divide 5730 by 3.5, which equals 1637.1′. The radii given in Table No. 29 are computed in this manner.

Length of curve. For a 5° curve a central angle of 5° subtends 100′ of arc; a central angle of 10°, 200′ of arc; a central angle of 12° 30′, 250′ of arc. That is, for a specified central angle the length of any specified curve equals that central angle expressed in degrees and decimals of a degree divided by the degree of curve expressed in degrees and decimals multiplied by 100; i.e., the length of a 10° 15′ curve for a central angle of 20° 45′ = $\frac{20.75}{10.25} \times 100' = 202.4'$ and is expressed by the formula

TABLE 30. FUNCTIONS OF A ONE-DEGREE CURVE FIGURED ON A BASIS OF $R = 5730'$ AND TABULATED TO TENTHS OF FEET

Use 100′ chords up to 8° Curves
Use 50′ chords up to 16° Curves
Use 25′ chords up to 32° Curves
Use 10′ chords above 32° Curves

Minutes	0°		1°		2°		3°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	0.0	0.0	0.2	50.0	0.9	100.0	2.0	150.1	0
10	0.0	8.3	0.3	58.3	1.0	108.4	2.2	158.4	10
20	0.0	16.7	0.4	66.7	1.2	116.7	2.4	166.8	20
30	0.1	25.0	0.5	75.0	1.4	125.0	2.7	175.1	30
40	0.1	33.3	0.6	83.3	1.6	133.4	2.9	183.4	40
50	0.2	41.7	0.7	91.7	1.8	141.7	3.2	191.7	50
60	0.2	50.0	0.9	100.0	2.0	150.1	3.5	200.1	60

Use 100′ chords up to 8° Curves
Use 50′ chords up to 16° Curves
Use 25′ chords up to 32° Curves
Use 10′ chords above 32° Curves

Minutes	Dec. of Degree	4° Ext.	4° Tan.	5° Ext.	5° Tan.	6° Ext.	6° Tan.	7° Ext.	7° Tan.	Minutes
0	.0000	3.5	200.1	5.5	250.2	7.9	300.3	10.7	350.4	0
1	.0167	3.5	200.9	5.5	251.0	7.9	301.1	10.8	351.3	1
2	.0333	3.6	201.8	5.5	251.8	8.0	302.0	10.8	352.1	2
3	.0500	3.6	202.6	5.6	252.7	8.0	302.8	10.9	352.9	3
4	.0667	3.6	203.4	5.6	253.5	8.0	303.6	10.9	353.8	4
5	.0833	3.6	204.3	5.6	254.3	8.1	304.5	11.0	354.6	5
6	.1000	3.7	205.1	5.7	255.2	8.1	305.3	11.0	355.5	6
7	.1167	3.7	205.9	5.7	256.0	8.2	306.1	11.1	356.3	7
8	.1333	3.7	206.8	5.8	256.8	8.2	307.0	11.1	357.1	8
9	.1500	3.8	207.6	5.8	257.7	8.3	307.8	11.2	358.0	9
10	.1667	3.8	208.4	5.8	258.5	8.3	308.6	11.2	358.8	10
11	.1833	3.8	209.3	5.9	259.3	8.4	309.5	11.3	359.6	11
12	.2000	3.9	210.1	5.9	260.2	8.4	310.3	11.3	360.5	12
13	.2167	3.9	210.9	5.9	261.0	8.4	311.1	11.4	361.3	13
14	.2333	3.9	211.8	6.0	261.9	8.5	312.0	11.4	362.2	14
15	.2500	3.9	212.6	6.0	262.7	8.5	312.8	11.5	363.0	15
16	.2667	4.0	213.4	6.1	263.5	8.6	313.7	11.5	363.8	16
17	.2833	4.0	214.3	6.1	264.4	8.6	314.5	11.6	364.7	17
18	.3000	4.0	215.1	6.1	265.2	8.7	315.3	11.7	365.5	18
19	.3167	4.1	215.9	6.2	266.0	8.7	316.2	11.7	366.3	19
20	.3333	4.1	216.8	6.2	266.9	8.8	317.0	11.8	367.2	20
21	.3500	4.1	217.6	6.2	267.7	8.8	317.8	11.8	368.0	21
22	.3667	4.2	218.4	6.3	268.5	8.9	318.7	11.9	368.8	22
23	.3833	4.2	219.3	6.3	269.4	8.9	319.5	11.9	369.7	23
24	.4000	4.2	220.1	6.4	270.2	9.0	320.3	12.0	370.5	24
25	.4167	4.3	220.9	6.4	271.0	9.0	321.2	12.0	371.4	25
26	.4333	4.3	221.8	6.4	271.9	9.0	322.0	12.1	372.2	26
27	.4500	4.3	222.6	6.5	272.7	9.1	322.8	12.1	373.0	27
28	.4667	4.4	223.5	6.5	273.5	9.1	323.7	12.2	373.9	28
29	.4833	4.4	224.3	6.5	274.4	9.2	324.5	12.2	374.7	29
30	.5000	4.4	225.1	6.6	275.2	9.2	325.4	12.3	375.5	30
31	.5167	4.5	226.0	6.6	276.1	9.3	326.2	12.4	376.4	31
32	.5333	4.5	226.8	6.7	276.9	9.3	327.0	12.4	377.2	32
33	.5500	4.5	227.6	6.7	277.7	9.4	327.9	12.5	378.1	33
34	.5667	4.6	228.5	6.8	278.6	9.4	328.7	12.5	378.9	34
35	.5833	4.6	229.3	6.8	279.4	9.5	329.5	12.6	379.7	35
36	.6000	4.6	230.1	6.8	280.2	9.5	330.4	12.6	380.6	36
37	.6167	4.7	231.0	6.9	281.1	9.6	331.2	12.7	381.4	37
38	.6333	4.7	231.8	6.9	281.9	9.6	332.0	12.7	382.2	38
39	.6500	4.7	232.6	7.0	282.7	9.7	332.9	12.8	383.1	39
40	.6667	4.8	233.5	7.0	283.6	9.7	333.7	12.9	383.9	40
41	.6833	4.8	234.3	7.1	284.4	9.8	334.6	12.9	384.7	41
42	.7000	4.8	235.1	7.1	285.2	9.8	335.4	13.0	385.6	42
43	.7167	4.9	236.0	7.1	286.1	9.9	336.2	13.0	386.4	43
44	.7333	4.9	236.8	7.2	286.9	9.9	337.1	13.1	387.3	44
45	.7500	4.9	237.6	7.2	287.7	10.0	337.9	13.1	388.1	45
46	.7667	5.0	238.5	7.3	288.6	10.0	338.7	13.2	388.9	46
47	.7833	5.0	239.3	7.3	289.4	10.1	339.6	13.2	389.8	47
48	.8000	5.0	240.1	7.3	290.3	10.1	340.4	13.3	390.6	48
49	.8167	5.1	241.0	7.4	291.1	10.2	341.2	13.4	391.4	49
50	.8333	5.1	241.8	7.4	291.9	10.2	342.1	13.4	392.3	50
51	.8500	5.1	242.6	7.5	292.8	10.3	342.9	13.5	393.1	51
52	.8667	5.2	243.5	7.5	293.6	10.3	343.7	13.5	394.0	52
53	.8833	5.2	244.3	7.5	294.4	10.4	344.6	13.6	394.8	53
54	.9000	5.2	245.2	7.6	295.3	10.4	345.4	13.7	395.6	54
55	.9167	5.3	246.0	7.6	296.1	10.5	346.3	13.7	396.5	55
56	.9333	5.3	246.8	7.7	296.9	10.5	347.1	13.8	397.3	56
57	.9500	5.3	247.7	7.7	297.8	10.6	347.9	13.8	398.1	57
58	.9667	5.4	248.5	7.8	298.6	10.6	348.8	13.9	399.0	58
	.9833	5.4	249.3	7.8	299.4	10.7	349.6	13.9	[illegible]	[illegible]

oo' Chords up to 8° Curves Use 25' Chords up to 32° Curves
o' Chords up to 16° Curves Use 10' Chords above 32° Curves

	8°		9°		10°		11°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	14.0	400.7	17.7	450.9	21.9	501.5	26.5	551.7	0
7	14.0	401.5	17.8	451.8	21.9	502.2	26.6	552.6	1
3	14.1	402.4	17.8	452.6	22.0	503.0	26.7	553.4	2
0	14.2	403.2	17.9	453.4	22.1	503.8	26.7	554.3	3
7	14.2	404.0	18.0	454.3	22.2	504.7	26.8	555.1	4
3	14.3	404.8	18.0	455.1	22.3	505.5	26.9	555.9	5
0	14.3	405.7	18.1	456.0	22.3	506.4	27.0	556.8	6
7	14.4	406.5	18.2	456.8	22.4	507.2	27.1	557.6	7
3	14.5	407.4	18.3	457.7	22.5	508.0	27.2	558.5	8
0	14.5	408.2	18.3	458.5	22.6	508.9	27.2	559.3	9
7	14.6	409.0	18.4	459.3	22.6	509.7	27.3	560.1	10
3	14.6	409.9	18.4	460.2	22.7	510.6	27.4	561.0	11
0	14.7	410.7	18.5	461.0	22.8	511.4	27.5	561.8	12
7	14.8	411.5	18.6	461.8	22.9	512.2	27.6	562.7	13
3	14.8	412.4	18.7	462.7	22.9	513.1	27.7	563.5	14
0	14.9	413.2	18.7	463.5	23.0	513.9	27.7	564.3	15
7	14.9	414.1	18.8	464.4	23.1	514.8	27.8	565.2	16
3	15.0	414.9	18.9	465.2	23.2	515.6	27.9	566.0	17
0	15.1	415.7	18.9	466.0	23.2	516.4	28.0	566.9	18
7	15.1	416.6	19.0	466.9	23.3	517.3	28.1	567.7	19
3	15.2	417.4	19.1	467.7	23.4	518.1	28.1	568.5	20
0	15.2	418.2	19.1	468.5	23.5	519.0	28.2	569.4	21
7	15.3	419.1	19.2	469.4	23.5	519.8	28.3	570.2	22
3	15.4	419.9	19.3	470.2	23.6	520.6	28.4	571.1	23
0	15.4	420.8	19.3	471.1	23.7	521.5	28.5	571.9	24
7	15.5	421.6	19.4	471.9	23.8	522.3	28.6	572.8	25
3	15.6	422.4	19.5	472.8	23.8	523.2	28.6	573.6	26
0	15.6	423.3	19.5	473.6	23.9	524.0	28.7	574.4	27
7	15.7	424.1	19.6	474.4	24.0	524.9	28.8	575.3	28
3	15.7	424.9	19.7	475.3	24.1	525.7	28.9	576.1	29
0	15.8	425.8	19.8	476.1	24.1	526.5	29.0	577.0	30
7	15.9	426.6	19.8	476.9	24.2	527.4	29.1	577.8	31
3	15.9	427.5	19.9	477.8	24.3	528.2	29.1	578.6	32
0	16.0	428.3	20.0	478.6	24.4	529.0	29.2	579.5	33
7	16.0	429.1	20.0	479.5	24.5	529.9	29.3	580.3	34
3	16.1	430.0	20.1	480.3	24.5	530.7	29.4	581.2	35
0	16.2	430.8	20.2	481.1	24.6	531.6	29.5	582.0	36
7	16.2	431.7	20.2	482.0	24.7	532.4	29.6	582.8	37
3	16.3	432.5	20.3	482.8	24.8	533.3	29.7	583.7	38
0	16.4	433.3	20.4	483.6	24.8	534.1	29.7	584.5	39
7	16.4	434.2	20.5	484.5	24.9	534.9	29.8	585.4	40
3	16.5	435.0	20.5	485.3	25.0	535.8	29.9	586.2	41
0	16.6	435.9	20.6	486.2	25.1	536.6	30.0	587.1	42
7	16.6	436.7	20.7	487.0	25.1	537.5	30.1	587.9	43
3	16.7	437.5	20.7	487.9	25.2	538.3	30.2	588.7	44
0	16.7	438.4	20.8	488.7	25.3	539.1	30.3	589.6	45
7	16.8	439.2	20.9	489.6	25.4	540.0	30.3	590.4	46
3	16.9	440.0	21.0	490.4	25.5	540.8	30.4	591.3	47
0	16.9	440.9	21.0	491.2	25.5	541.7	30.5	592.1	48
7	17.0	441.7	21.1	492.0	25.6	542.5	30.6	592.9	49
3	17.1	442.5	21.2	492.9	25.7	543.3	30.7	593.8	50
0	17.1	443.4	21.2	493.7	25.8	544.2	30.8	594.6	51
7	17.2	444.2	21.3	494.6	25.9	545.0	30.9	595.5	52
3	17.3	445.1	21.4	495.4	25.9	545.9	31.0	596.3	53
0	17.3	445.9	21.5	496.3	26.0	546.7	31.0	597.2	54
7	17.4	446.7	21.5	497.1	26.1	547.5	31.1	598.0	55
3	17.5	447.6	21.6	498.0	26.2	548.4	31.2	598.8	56
	17.5	448.4	21.7	498.8	26.3	549.2	31.3	599.7	57
	17.6	449.3	21.8	499.6	26.3	550.1	31.4	600.5	58
	17.6	450.1	21.8	500.4	26.4	550.9	31.5	601.[illegible]	

Use 100′ Chords up to 8° Curves   Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves   Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	12° Ext.	12° Tan.	13° Ext.	13° Tan.	14° Ext.	14° Tan.	15° Ext.	15° Tan.
0	.0000	31.6	602.2	37.1	652.9	43.0	703.5	49.4	754.4
1	.0167	31.7	603.1	37.2	653.7	43.1	704.4	49.6	755.2
2	.0333	31.7	603.9	37.3	654.6	43.2	705.2	49.7	756.1
3	.0500	31.8	604.7	37.4	655.4	43.3	706.1	49.8	756.9
4	.0667	31.9	605.6	37.5	656.3	43.4	706.9	49.9	757.7
5	.0833	32.0	606.4	37.6	657.1	43.5	707.8	50.0	758.6
6	.1000	32.1	607.3	37.7	657.9	43.7	708.6	50.1	759.4
7	.1167	32.2	608.1	37.7	658.8	43.8	709.5	50.2	760.3
8	.1333	32.3	609.0	37.8	659.6	43.9	710.3	50.3	761.1
9	.1500	32.4	609.8	37.9	660.5	44.0	711.2	50.5	762.0
10	.1667	32.5	610.7	38.0	661.3	44.1	712.0	50.6	762.8
11	.1833	32.5	611.5	38.1	662.2	44.2	712.9	50.7	763.7
12	.2000	32.6	612.4	38.2	663.0	44.3	713.7	50.8	764.5
13	.2167	32.7	613.2	38.3	663.8	44.4	714.6	50.9	765.4
14	.2333	32.8	614.0	38.4	664.7	44.5	715.4	51.0	766.2
15	.2500	32.9	614.9	38.5	665.5	44.6	716.3	51.1	767.1
16	.2667	33.0	615.7	38.6	666.4	44.7	717.1	51.2	767.9
17	.2833	33.1	616.6	38.7	667.2	44.8	718.0	51.3	768.8
18	.3000	33.2	617.4	38.8	668.1	44.9	718.8	51.5	769.6
19	.3167	33.3	618.3	38.9	668.9	45.0	719.6	51.6	770.5
20	.3333	33.4	619.1	39.0	669.8	45.1	720.5	51.7	771.3
21	.3500	33.4	619.9	39.1	670.6	45.2	721.3	51.8	772.2
22	.3667	33.5	620.8	39.2	671.4	45.3	722.2	51.9	773.0
23	.3833	33.6	621.6	39.3	672.3	45.4	723.1	52.0	773.9
24	.4000	33.7	622.5	39.4	673.1	45.5	723.9	52.1	774.7
25	.4167	33.8	623.3	39.5	674.0	45.6	724.7	52.3	775.6
26	.4333	33.9	624.2	39.6	674.8	45.8	725.6	52.4	776.4
27	.4500	34.0	625.0	39.7	675.7	45.9	726.5	52.5	777.3
28	.4667	34.1	625.9	39.8	676.5	46.0	727.3	52.6	778.1
29	.4833	34.2	626.7	39.9	677.4	46.1	728.1	52.7	778.9
30	.5000	34.3	627.6	40.0	678.2	46.2	729.0	52.8	779.8
31	.5167	34.4	628.4	40.1	679.0	46.3	729.8	52.9	780.6
32	.5333	34.5	629.2	40.2	679.9	46.4	730.7	53.1	781.5
33	.5500	34.5	630.1	40.3	680.7	46.5	731.5	53.2	782.3
34	.5667	34.6	630.9	40.4	681.6	46.6	732.4	53.3	783.2
35	.5833	34.7	631.8	40.5	682.4	46.7	733.2	53.4	784.0
36	.6000	34.8	632.6	40.6	683.3	46.8	734.0	53.5	784.9
37	.6167	34.9	633.5	40.7	684.1	46.9	734.9	53.6	785.7
38	.6333	35.0	634.3	40.8	685.0	47.0	735.7	53.7	786.6
39	.6500	35.1	635.1	40.9	685.8	47.2	736.6	53.9	787.4
40	.6667	35.2	636.0	41.0	686.6	47.3	737.4	54.0	788.3
41	.6833	35.3	636.8	41.1	687.5	47.4	738.3	54.1	789.1
42	.7000	35.4	637.7	41.2	688.4	47.5	739.1	54.2	790.0
43	.7167	35.5	638.5	41.3	689.2	47.6	740.0	54.3	790.8
44	.7333	35.6	639.4	41.4	690.0	47.7	740.8	54.4	791.7
45	.7500	35.7	640.2	41.5	690.9	47.8	741.7	54.6	792.5
46	.7667	35.8	641.1	41.6	691.7	47.9	742.5	54.7	793.4
47	.7833	35.8	641.9	41.7	692.5	48.0	743.4	54.8	794.2
48	.8000	35.9	642.7	41.8	693.4	48.1	744.2	54.9	795.1
49	.8167	36.0	643.6	41.9	694.2	48.2	745.1	55.0	795.9
50	.8333	36.1	644.4	42.0	695.1	48.3	745.9	55.1	796.8
51	.8500	36.2	645.3	42.1	695.9	48.5	746.7	55.3	797.6
52	.8667	36.3	646.1	42.2	696.8	48.6	747.6	55.4	798.5
53	.8833	36.4	647.0	42.3	697.6	48.7	748.4	55.5	799.3
54	.9000	36.5	647.8	42.4	698.5	48.8	749.3	55.6	800.2
55	.9167	36.6	648.6	42.5	699.3	48.9	750.1	55.7	801.0
56	.9333	36.7	649.5	42.6	700.1	49.0	751.0	55.8	801.9
57	.9500	36.8	650.3	42.7	701.0	49.1	751.8	56.0	[illegible]
58	.9667	36.9	651.2	42.8	701.8	49.2	752.7	56.1	[illegible]
59	.9833	37.0	652.0	42.9	702.7	49.3	753.5	56.2	[illegible]

oo′ Chords up to 8° Curves — Use 25′ Chords up to 32° Curves
o′ Chords up to 16° Curves — Use 10′ Chords above 32° Curves

16°		17°		18°		19°		Minutes
Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
56.3	805.3	63.6	856.4	71.4	907.5	79.7	958.9	0
56.4	806.2	63.8	857.2	71.6	908.4	79.8	959.7	1
56.5	807.0	63.9	858.1	71.7	909.2	79.9	960.6	2
56.7	807.8	64.0	858.9	71.8	910.1	80.1	961.4	3
56.8	808.6	64.2	859.8	72.0	910.9	80.2	962.3	4
56.9	809.5	64.3	860.6	72.1	911.8	80.4	963.2	5
57.0	810.4	64.4	861.5	72.2	912.7	80.5	964.0	6
57.1	811.2	64.5	862.3	72.4	913.5	80.7	964.9	7
57.3	812.1	64.7	863.2	72.5	914.4	80.8	965.7	8
57.4	812.9	64.8	864.0	72.6	915.2	80.9	966.6	9
57.5	813.8	64.9	864.9	72.8	916.1	81.1	967.4	10
57.6	814.6	65.0	865.7	72.9	916.9	81.2	968.3	11
57.7	815.5	65.2	866.6	73.0	917.8	81.4	969.2	12
57.9	816.3	65.3	867.4	73.2	918.6	81.5	970.0	13
58.0	817.2	65.4	868.3	73.3	919.5	81.7	970.9	14
58.1	818.0	65.6	869.1	73.4	920.3	81.8	971.7	15
58.2	818.9	65.7	870.0	73.6	921.2	81.9	972.6	16
58.3	819.7	65.8	870.8	73.7	922.0	82.1	973.4	17
58.5	820.6	65.9	871.7	73.9	922.9	82.2	974.3	18
58.6	821.4	66.1	872.5	74.0	923.8	82.4	975.1	19
58.7	822.3	66.2	873.4	74.1	924.6	82.5	976.0	20
58.8	823.1	66.3	874.2	74.3	925.5	82.7	976.9	21
58.9	824.0	66.4	875.1	74.4	926.3	82.8	977.7	22
59.1	824.8	66.6	875.9	74.5	927.2	82.9	978.6	23
59.2	825.7	66.7	876.8	74.7	928.1	83.1	979.4	24
59.3	826.5	66.8	877.6	74.8	928.9	83.2	980.3	25
59.4	827.4	67.0	878.5	74.9	929.8	83.4	981.2	26
59.6	828.2	67.1	879.3	75.1	930.6	83.5	982.0	27
59.7	829.1	67.2	880.2	75.2	931.5	83.7	982.9	28
59.8	829.9	67.3	881.0	75.4	932.3	83.8	983.7	29
59.9	830.8	67.5	881.9	75.5	933.2	84.0	984.6	30
60.0	831.6	67.6	882.7	75.6	934.0	84.1	985.4	31
60.2	832.5	67.7	883.6	75.8	934.9	84.3	986.3	32
60.3	833.3	67.9	884.5	75.9	935.7	84.4	987.2	33
60.4	834.2	68.0	885.3	76.1	936.6	84.6	988.0	34
60.5	835.1	68.1	886.2	76.2	937.5	84.7	988.9	35
60.7	835.9	68.2	887.0	76.3	938.3	84.8	989.7	36
60.8	836.8	68.4	887.9	76.5	939.2	85.0	990.6	37
60.9	837.6	68.5	888.7	76.6	940.0	85.1	991.5	38
61.0	838.5	68.6	889.6	76.7	940.9	85.3	992.3	39
61.1	839.3	68.8	890.4	76.9	941.7	85.4	993.2	40
61.3	840.2	68.9	891.3	77.0	942.6	85.6	994.0	41
61.4	841.0	69.0	892.2	77.1	943.5	85.7	994.9	42
61.5	841.9	69.2	893.0	77.3	944.3	85.9	995.8	43
61.6	842.7	69.3	893.9	77.4	945.2	86.0	996.6	44
61.8	843.6	69.4	894.7	77.6	946.0	86.2	997.5	45
61.9	844.4	69.6	895.6	77.7	946.9	86.3	998.3	46
62.0	845.3	69.7	896.4	77.8	947.7	86.5	999.2	47
62.1	846.1	69.8	897.3	78.0	948.6	86.6	1000.0	48
62.3	847.0	70.0	898.1	78.1	949.4	86.8	1000.9	49
62.4	847.8	70.1	899.0	78.3	950.3	86.9	1001.8	50
62.5	848.7	70.2	899.8	78.4	951.1	87.1	1002.6	51
62.6	849.5	70.4	900.7	78.5	952.0	87.2	1003.5	52
62.8	850.4	70.5	901.5	78.7	952.9	87.4	1004.3	53
62.9	851.2	70.6	902.4	78.8	953.7	87.5	1005.2	54
63.0	852.1	70.8	903.3	79.0	954.6	87.7	1006.0	55
63.1	852.9	70.9	904.1	79.1	955.4	87.8	1006.9	56
63.3	853.8	71.0	905.0	79.2	956.3	88.0	1007.7	57
63.4	854.7	71.2	905.8	79.4	957.2	88.1	1008.6	58
63.5	855.5	71.3	906.7	79.5	958.0	88.2	1009.5	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32°
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32°

Minutes	Dec. of Degree	20° Ext.	20° Tan.	21° Ext.	21° Tan.	22° Ext.	22° Tan.	Ext
0	.0000	88.4	1010.4	97.6	1062.0	107.2	1113.8	117
1	.0167	88.5	1011.2	97.7	1062.8	107.4	1114.6	117
2	.0333	88.7	1012.1	97.9	1063.7	107.6	1115.5	117
3	.0500	88.8	1012.9	98.1	1064.5	107.7	1116.4	117
4	.0667	89.0	1013.8	98.2	1065.4	107.9	1117.3	118
5	.0833	89.1	1014.6	98.4	1066.3	108.0	1118.1	118
6	.1000	89.3	1015.5	98.5	1067.2	108.2	1119.0	118
7	.1167	89.4	1016.3	98.7	1068.0	108.4	1119.8	118.
8	.1333	89.6	1017.2	98.8	1068.9	108.6	1120.7	118.
9	.1500	89.7	1018.1	99.0	1069.7	108.7	1121.5	118
10	.1667	89.9	1019.0	99.2	1070.6	108.9	1122.4	119.
11	.1833	90.0	1019.8	99.3	1071.5	109.0	1123.3	119.
12	.2000	90.2	1020.7	99.5	1072.4	109.2	1124.2	119.
13	.2167	90.3	1021.5	99.6	1073.2	109.4	1125.0	119.
14	.2333	90.5	1022.4	99.8	1074.1	109.6	1125.9	119.
15	.2500	90.6	1023.2	99.9	1074.9	109.7	1126.7	120.
16	.2667	90.8	1024.1	100.1	1075.8	109.9	1127.6	120.
17	.2833	90.9	1024.9	100.2	1076.6	110.0	1128.5	120.
18	.3000	91.1	1025.8	100.4	1077.5	110.2	1129.4	120.
19	.3167	91.2	1026.7	100.5	1078.4	110.4	1130.2	120.
20	.3333	91.4	1027.6	100.7	1079.3	110.6	1131.1	120.
21	.3500	91.6	1028.4	100.9	1080.1	110.7	1131.9	121
22	.3667	91.7	1029.5	101.1	1081.0	110.9	1132.8	121
23	.3833	91.9	1030.1	101.2	1081.8	111.0	1133.7	121
24	.4000	92.0	1031.0	101.4	1082.7	111.2	1134.6	121.
25	.4167	92.2	1031.8	101.5	1083.5	111.4	1135.4	121.
26	.4333	92.3	1032.7	101.7	1084.4	111.6	1136.3	121.
27	.4500	92.5	1033.5	101.8	1085.3	111.7	1137.1	122
28	.4667	92.6	1034.4	102.0	1086.2	111.9	1138.0	122.
29	.4833	92.8	1035.2	102.1	1087.0	112.1	1138.8	122.
30	.5000	92.9	1036.1	102.3	1087.9	112.3	1139.7	122
31	.5167	93.1	1037.0	102.5	1088.7	112.4	1140.6	122
32	.5333	93.2	1037.9	102.7	1089.6	112.6	1141.5	123.
33	.5500	93.4	1038.7	102.8	1090.4	112.7	1142.3	123
34	.5667	93.5	1039.6	103.0	1091.3	112.9	1143.2	123.
35	.5833	93.7	1040.4	103.1	1092.2	113.1	1144.0	123.
36	.6000	93.9	1041.3	103.3	1093.1	113.3	1144.9	123.
37	.6167	94.0	1042.1	103.4	1093.9	113.4	1145.8	123.
38	.6333	94.2	1043.0	103.6	1094.8	113.6	1146.7	124
39	.6500	94.3	1043.9	103.8	1095.6	113.7	1147.5	124.
40	.6667	94.5	1044.8	104.0	1096.5	113.9	1148.4	124.
41	.6833	94.6	1045.6	104.1	1097.4	114.1	1149.2	124
42	.7000	94.8	1046.5	104.3	1098.3	114.3	1150.1	124.
43	.7167	94.9	1047.3	104.4	1099.1	114.4	1151.0	124.
44	.7333	95.1	1048.2	104.6	1100.0	114.6	1151.9	125.
45	.7500	95.2	1049.0	104.7	1100.8	114.8	1152.7	125.
46	.7667	95.4	1049.9	104.9	1101.7	115.0	1153.6	125.
47	.7833	95.6	1050.8	105.1	1102.5	115.2	1154.5	125.
48	.8000	95.7	1051.7	105.3	1103.4	115.3	1155.4	125
49	.8167	95.9	1052.5	105.4	1104.3	115.5	1156.2	126.
50	.8333	96.0	1053.4	105.6	1105.2	115.7	1157.1	126.
51	.8500	96.2	1054.2	105.7	1106.0	115.8	1157.9	126.
52	.8667	96.3	1055.1	105.9	1106.9	116.0	1158.8	126.
53	.8833	96.5	1055.9	106.1	1107.8	116.1	1159.7	126.
54	.9000	96.7	1056.8	106.3	1108.6	116.3	1160.6	126.
55	.9167	96.8	1057.7	106.4	1109.4	116.5	1161.4	127
56	.9333	97.0	1058.6	106.6	1110.3	116.7	1162.3	127
57	.9500	97.1	1059.4	106.7	1111.2	116.8	1163.1	12
58	.9667	97.3	1060.3	106.9	1112.1	117.0	1164.0	1
59	.9833	97.4	1061.1	107.0	1112.9	117.2	1164.9	

e 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
e 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Degree	24° Ext.	24° Tan.	25° Ext.	25° Tan.	26° Ext.	26° Tan.	27° Ext.	27° Tan.	Minutes
000	128.0	1218.0	139.1	1270.3	150.7	1322.9	162.8	1375.6	0
167	128.2	1218.8	139.3	1271.1	150.9	1323.7	163.0	1376.5	1
333	128.4	1219.7	139.5	1272.0	151.1	1324.6	163.2	1377.4	2
500	128.5	1220.5	139.7	1272.9	151.3	1325.5	163.5	1378.3	3
667	128.7	1221.4	139.9	1273.8	151.5	1326.4	163.7	1379.2	4
833	128.9	1222.3	140.1	1274.6	151.7	1327.3	163.9	1380.0	5
000	129.1	1223.2	140.3	1275.5	151.9	1328.1	164.1	1380.9	6
167	129.3	1224.0	140.4	1276.4	152.1	1329.0	164.3	1381.8	7
333	129.5	1224.9	140.6	1277.3	152.3	1329.9	164.5	1382.7	8
500	129.7	1225.8	140.8	1278.2	152.5	1330.7	164.7	1383.6	9
667	129.8	1226.7	141.0	1279.1	152.7	1331.6	164.9	1384.5	10
833	130.0	1227.5	141.2	1279.9	152.9	1332.5	165.1	1385.3	11
000	130.2	1228.4	141.4	1280.8	153.1	1333.4	165.3	1386.2	12
167	130.4	1229.3	141.6	1281.6	153.3	1334.3	165.5	1387.1	13
333	130.6	1230.2	141.8	1282.5	153.5	1335.2	165.7	1388.0	14
500	130.7	1231.0	142.0	1283.4	153.7	1336.0	165.9	1388.9	15
667	130.9	1231.9	142.2	1284.3	153.9	1336.9	166.1	1389.8	16
833	131.1	1232.7	142.3	1285.2	154.1	1337.8	166.3	1390.6	17
000	131.3	1233.6	142.5	1286.1	154.3	1338.7	166.5	1391.5	18
167	131.5	1234.5	142.7	1286.9	154.5	1339.5	166.7	1392.4	19
333	131.7	1235.4	142.9	1287.8	154.7	1340.4	167.0	1393.3	20
500	131.9	1236.2	143.1	1288.7	154.9	1341.3	167.2	1394.1	21
667	132.0	1237.1	143.3	1289.6	155.1	1342.2	167.4	1395.0	22
833	132.2	1238.0	143.5	1290.4	155.3	1343.0	167.6	1395.9	23
000	132.4	1238.9	143.7	1291.3	155.5	1343.9	167.8	1396.8	24
167	132.6	1239.7	143.9	1292.2	155.7	1344.8	168.0	1397.7	25
333	132.8	1240.6	144.1	1293.1	155.9	1345.7	168.2	1398.6	26
500	133.0	1241.5	144.3	1293.9	156.1	1346.5	168.4	1399.4	27
667	133.1	1242.4	144.5	1294.8	156.3	1347.4	168.6	1400.3	28
833	133.3	1243.2	144.7	1295.7	156.5	1348.3	168.9	1401.2	29
000	133.5	1244.1	144.9	1296.6	156.7	1349.2	169.1	1402.1	30
167	133.7	1244.9	145.1	1297.4	156.9	1350.1	169.3	1403.0	31
333	133.9	1245.8	145.3	1298.3	157.1	1351.0	169.5	1403.9	32
500	134.0	1246.7	145.5	1299.2	157.3	1351.8	169.7	1404.7	33
667	134.2	1247.6	145.6	1300.1	157.5	1352.7	169.9	1405.6	34
833	134.4	1248.4	145.8	1300.9	157.7	1353.6	170.1	1406.5	35
000	134.6	1249.3	146.0	1301.8	157.9	1354.5	170.3	1407.4	36
167	134.9	1250.2	146.2	1302.7	158.1	1355.5	170.5	1408.3	37
333	135.0	1251.1	146.4	1303.6	158.3	1356.2	170.8	1409.2	38
500	135.2	1251.9	146.6	1304.4	158.5	1357.1	171.0	1410.0	39
667	135.4	1252.8	146.8	1305.3	158.7	1358.0	171.2	1410.9	40
833	135.6	1253.7	147.0	1306.2	158.9	1358.9	171.4	1411.8	41
000	135.7	1254.6	147.2	1307.1	159.1	1359.8	171.6	1412.7	42
167	135.9	1255.4	147.4	1307.9	159.3	1360.6	171.8	1413.6	43
333	136.1	1256.3	147.6	1308.8	159.5	1361.5	172.0	1414.5	44
00	136.3	1257.2	147.8	1309.7	159.7	1362.4	172.2	1415.4	45
67	136.5	1258.1	148.0	1310.6	160.0	1363.3	172.5	1416.3	46
33	136.7	1259.0	148.2	1311.5	160.2	1364.2	172.7	1417.1	47
00	136.9	1259.8	148.4	1312.4	160.4	1365.1	172.9	1418.0	48
67	137.1	1260.7	148.6	1313.2	160.6	1365.9	173.1	1418.9	49
33	137.2	1261.5	148.8	1314.1	160.8	1366.8	173.3	1419.8	50
00	137.4	1262.4	149.0	1315.0	161.0	1367.7	173.5	1420.7	51
67	137.6	1263.3	149.2	1315.9	161.2	1368.6	173.7	1421.6	52
33	137.8	1264.1	149.4	1316.7	161.4	1369.5	173.9	1422.4	53
00	138.0	1265.0	149.5	1317.6	161.6	1370.4	174.1	1423.3	54
67	138.2	1265.9	149.7	1318.5	161.8	1371.2	174.4	1424.2	55
3	138.4	1266.8	149.9	1319.4	162.0	1372.1	174.6	1425.1	56
0	138.6	1267.6	150.1	1320.3	162.2	1373.0	174.8	1426.0	57
	138.7	1268.5	150.3	1321.1	162.4	1373.9	175.0	1426.9	58
	138.9	1269.4	150.5	1322.0	162.6	1374.7	175.2	1427.7	60

Use 100' Chords up to 8° Curves Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves Use 10' Chords above 32° Curves

Minutes	Dec of Degree	28° Ext.	28° Tan.	29° Ext.	29° Tan.	30° Ext.	30° Tan.	31° Ext.	31° Tan.	Minutes
0	.0000	175.4	1428.6	188.5	1481.9	202.1	1535.3	216.3	1589.0	0
1	.0167	175.6	1429.5	188.7	1482.8	202.4	1536.2	216.5	1589.9	1
2	.0333	175.8	1430.4	189.0	1483.7	202.6	1537.1	216.8	1590.8	2
3	.0500	176.0	1431.3	189.2	1484.5	202.8	1538.0	217.0	1591.7	3
4	.0667	176.3	1432.2	189.4	1485.4	203.1	1538.9	217.2	1592.6	4
5	.0833	176.5	1433.1	189.6	1486.3	203.3	1539.8	217.4	1593.5	5
6	.1000	176.7	1434.0	189.9	1487.2	203.5	1540.7	217.7	1594.4	6
7	.1167	176.9	1434.8	190.1	1488.1	203.7	1541.6	217.9	1595.3	7
8	.1333	177.1	1435.7	190.3	1489.0	204.0	1542.5	218.2	1596.2	8
9	.1500	177.3	1436.6	190.5	1489.9	204.2	1543.4	218.4	1597.1	9
10	.1667	177.6	1437.5	190.8	1490.8	204.5	1544.3	218.7	1598.0	10
11	.1833	177.8	1438.4	191.0	1491.7	204.7	1545.2	218.9	1598.9	11
12	.2000	178.0	1439.3	191.2	1492.6	204.9	1546.0	219.2	1599.8	12
13	.2167	178.2	1440.2	191.5	1493.4	205.1	1546.9	219.4	1600.7	13
14	.2333	178.4	1441.1	191.7	1494.3	205.4	1547.8	219.6	1601.6	14
15	.2500	178.6	1441.9	191.9	1495.2	205.6	1548.7	219.8	1602.5	15
16	.2667	178.9	1442.8	192.1	1496.1	205.9	1549.6	220.1	1603.4	16
17	.2833	179.1	1443.7	192.3	1497.0	206.1	1550.5	220.3	1604.3	17
18	.3000	179.3	1444.6	192.5	1497.9	206.3	1551.4	220.6	1605.2	18
19	.3167	179.5	1445.5	192.7	1498.8	206.5	1552.3	220.8	1606.1	19
20	.3333	179.7	1446.4	193.0	1499.7	206.8	1553.2	221.1	1607.0	20
21	.3500	179.9	1447.3	193.2	1500.6	207.0	1554.1	221.3	1607.9	21
22	.3667	180.2	1448.2	193.5	1501.5	207.3	1555.0	221.6	1608.8	22
23	.3833	180.4	1449.0	193.7	1502.3	207.5	1555.9	221.8	1609.7	23
24	.4000	180.6	1449.9	193.9	1503.2	207.7	1556.8	222.1	1610.6	24
25	.4167	180.8	1450.8	194.1	1504.1	207.9	1557.7	222.3	1611.5	25
26	.4333	181.0	1451.7	194.4	1505.0	208.2	1558.6	222.6	1612.4	26
27	.4500	181.2	1452.6	194.6	1505.9	208.4	1559.5	222.8	1613.3	27
28	.4667	181.5	1453.5	194.8	1506.8	208.7	1560.4	223.0	1614.2	28
29	.4833	181.7	1454.3	195.0	1507.7	208.9	1561.3	223.2	1615.1	29
30	.5000	181.9	1455.2	195.3	1508.6	209.1	1562.2	223.5	1616.0	30
31	.5167	182.1	1456.1	195.5	1509.5	209.3	1563.1	223.7	1616.9	31
32	.5333	182.3	1457.0	195.7	1510.4	209.6	1564.0	224.0	1617.8	32
33	.5500	182.5	1457.9	195.9	1511.2	209.8	1564.9	224.2	1618.7	33
34	.5667	182.8	1458.8	196.2	1512.1	210.1	1565.7	224.5	1619.6	34
35	.5833	183.0	1459.7	196.4	1513.0	210.3	1566.6	224.7	1620.5	35
36	.6000	183.2	1460.6	196.7	1513.9	210.5	1567.5	225.0	1621.4	36
37	.6167	183.4	1461.4	196.9	1514.8	210.7	1568.4	225.2	1622.3	37
38	.6333	183.6	1462.3	197.1	1515.7	211.0	1569.3	225.5	1623.2	38
39	.6500	183.8	1463.2	197.3	1516.6	211.2	1570.2	225.7	1624.1	39
40	.6667	184.1	1464.1	197.6	1517.5	211.5	1571.1	226.0	1625.0	40
41	.6833	184.3	1465.0	197.8	1518.4	211.7	1572.0	226.2	1625.9	41
42	.7000	184.5	1465.9	198.0	1519.3	212.0	1572.9	226.5	1626.8	42
43	.7167	184.7	1466.8	198.2	1520.1	212.2	1573.8	226.7	1627.7	43
44	.7333	185.0	1467.7	198.5	1521.0	212.4	1574.7	227.0	1628.6	44
45	.7500	185.2	1468.6	198.7	1521.9	212.6	1575.6	227.2	1629.5	45
46	.7667	185.4	1469.5	198.9	1522.8	212.9	1576.5	227.5	1630.5	46
47	.7833	185.6	1470.4	199.1	1523.7	213.1	1577.4	227.7	1631.4	47
48	.8000	185.9	1471.2	199.4	1524.6	213.4	1578.3	228.0	1632.3	48
49	.8167	186.1	1472.1	199.6	1525.5	213.6	1579.2	228.2	1633.2	49
50	.8333	186.3	1473.0	199.8	1526.4	213.9	1580.1	228.4	1634.1	50
51	.8500	186.5	1473.9	200.0	1527.3	214.1	1581.0	228.6	1635.0	51
52	.8667	186.8	1474.8	200.3	1528.2	214.4	1581.9	228.9	1635.9	52
53	.8833	187.0	1475.7	200.5	1529.1	214.6	1582.8	229.1	1636.8	53
54	.9000	187.2	1476.6	200.8	1530.0	214.8	1583.7	229.4	1637.7	54
55	.9167	187.4	1477.4	201.0	1530.9	215.0	1584.6	229.6	1638.6	55
56	.9333	187.6	1478.3	201.2	1531.7	215.3	1585.5	229.9	1639.5	56
57	.9500	187.8	1479.2	201.4	1532.6	215.5	1586.3	230.1	[illegible]	
58	.9667	188.1	1480.1	201.7	1533.5	215.8	1587.2	230.4	[illegible]	
59	.9833	188.3	1481.0	201.9	1534.4	216.0	1588.1	230.6	1642.2	

100' Chords up to 8° Curves Use 25' Chords up to 32° Curves
50' Chords up to 16° Curves Use 10' Chords above 32° Curves

Degree	32°		33°		34°		35°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
00	230.9	1643.1	246.1	1697.3	261.8	1751.8	278.1	1806.7	0
67	231.1	1644.0	246.3	1698.2	262.0	1752.7	278.4	1807.6	1
33	231.4	1644.9	246.6	1699.1	262.3	1753.7	278.6	1808.5	2
00	231.6	1645.8	246.8	1700.0	262.6	1754.6	278.9	1809.4	3
67	231.9	1646.7	247.1	1700.9	262.9	1755.5	279.2	1810.3	4
33	232.1	1647.6	247.4	1701.8	263.1	1756.4	279.4	1811.2	5
00	232.4	1648.5	247.7	1702.7	263.4	1757.3	279.7	1812.1	6
67	232.6	1649.4	247.9	1703.6	263.7	1758.2	280.0	1813.1	7
33	232.9	1650.3	248.2	1704.5	264.0	1759.1	280.3	1814.0	8
00	233.1	1651.2	248.4	1705.4	264.2	1760.0	280.6	1814.9	9
67	233.4	1652.1	248.7	1706.4	264.5	1761.0	280.8	1815.8	10
33	233.6	1653.0	249.0	1707.3	264.7	1761.9	281.1	1816.7	11
00	233.9	1653.9	249.2	1708.2	265.0	1762.8	281.4	1817.7	12
67	234.1	1654.8	249.4	1709.1	265.3	1763.7	281.6	1818.6	13
33	234.4	1655.7	249.7	1710.0	265.6	1764.6	281.9	1819.5	14
00	234.6	1656.6	249.9	1710.9	265.9	1765.5	282.2	1820.4	15
67	234.9	1657.5	250.2	1711.8	266.1	1766.4	282.5	1821.3	16
33	235.1	1658.4	250.5	1712.7	266.4	1767.3	282.7	1822.2	17
00	235.4	1659.3	250.8	1713.6	266.7	1768.3	283.0	1823.2	18
67	235.6	1660.2	251.0	1714.5	266.9	1769.2	283.3	1824.1	19
33	235.9	1661.1	251.3	1715.5	267.2	1770.1	283.6	1825.0	20
00	236.1	1662.0	251.5	1716.4	267.4	1771.0	283.9	1825.9	21
67	236.4	1662.9	251.8	1717.3	267.7	1771.9	284.2	1826.8	22
33	236.6	1663.8	252.0	1718.2	268.0	1772.8	284.4	1827.7	23
00	236.9	1664.7	252.3	1719.1	268.3	1773.7	284.7	1828.7	24
67	237.1	1665.6	252.6	1720.0	268.6	1774.6	285.0	1829.6	25
33	237.4	1666.5	252.9	1720.9	268.8	1775.6	285.3	1830.5	26
00	237.6	1667.4	253.1	1721.8	269.1	1776.5	285.6	1831.4	27
67	237.9	1668.3	253.4	1722.7	269.3	1777.4	285.9	1832.3	28
33	238.1	1669.2	253.6	1723.6	269.6	1778.3	286.1	1833.2	29
00	238.4	1670.1	253.9	1724.6	269.9	1779.2	286.4	1834.2	30
67	238.7	1671.0	254.1	1725.5	270.1	1780.1	286.7	1835.1	31
33	239.0	1671.9	254.4	1726.4	270.4	1781.0	287.0	1836.0	32
00	239.2	1672.8	254.7	1727.3	270.7	1781.9	287.2	1836.9	33
67	239.5	1673.7	255.0	1728.2	271.0	1782.9	287.5	1837.8	34
33	239.7	1674.6	255.2	1729.1	271.2	1783.8	287.8	1838.7	35
00	240.0	1675.5	255.5	1730.0	271.5	1784.7	288.1	1839.7	36
67	240.2	1676.4	255.7	1730.9	271.7	1785.6	288.4	1840.6	37
33	240.5	1677.4	256.0	1731.8	272.0	1786.5	288.7	1841.5	38
00	240.7	1678.3	256.2	1732.7	272.3	1787.4	289.0	1842.4	39
67	241.0	1679.2	256.5	1733.6	272.6	1788.4	289.2	1843.4	40
33	241.2	1680.1	256.8	1734.5	272.9	1789.3	289.5	1844.3	41
00	241.5	1681.0	257.1	1735.5	273.1	1790.2	289.8	1845.2	42
67	241.7	1681.9	257.3	1736.4	273.4	1791.1	290.1	1846.1	43
33	242.0	1682.8	257.6	1737.3	273.7	1792.0	290.4	1847.1	44
00	242.2	1683.7	257.8	1738.2	274.0	1792.9	290.6	1848.0	45
67	242.5	1684.6	258.1	1739.1	274.2	1793.9	290.9	1848.9	46
33	242.7	1685.5	258.3	1740.0	274.5	1794.8	291.2	1849.8	47
00	243.0	1686.4	258.6	1740.9	274.8	1795.7	291.5	1850.7	48
67	243.2	1687.3	258.9	1741.8	275.0	1796.6	291.8	1851.6	49
33	243.5	1688.2	259.1	1742.7	275.3	1797.5	292.0	1852.6	50
00	243.8	1689.1	259.4	1743.6	275.6	1798.4	292.3	1853.5	51
67	244.1	1690.0	259.7	1744.6	275.9	1799.3	292.6	1854.4	52
33	244.3	1690.9	259.9	1745.5	276.1	1800.2	292.9	1855.3	53
00	244.6	1691.8	260.2	1746.4	276.4	1801.2	293.2	1856.3	54
67	244.8	1692.7	260.5	1747.3	276.7	1802.1	293.4	1857.2	55
33	245.1	1693.7	260.9	1748.2	277.0	1803.0	293.7	1858.1	56
00	245.3	1694.6	261.0	1749.1	277.3	1803.9	294.0	1859.0	57
7	245.6	1695.5	261.3	1750.0	277.5	1804.8	294.3	1859.9	58
[illegible]	245.8	1696.4	261.5	1750.9	277.8	1805.7	294.6	1860.8	59

Use 100' Chords up to 8° Curves Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves Use 10' Chords above 32° Curves

Minutes	Dec of Degree	36°		37°		38°		39°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	294.9	1861.8	312.3	1917.3	330.2	1973.0	348.7	2029.1	0
1	.0167	295.2	1862.7	312.5	1918.2	330.5	1973.9	349.0	2030.0	1
2	.0333	295.4	1863.6	312.8	1919.1	330.8	1974.9	349.3	2031.0	2
3	.0500	295.7	1864.5	313.1	1920.0	331.1	1975.8	349.6	2031.9	3
4	.0667	296.0	1865.5	313.4	1921.0	331.4	1976.7	349.9	2032.9	4
5	.0833	296.3	1866.4	313.7	1921.9	331.7	1977.6	350.3	2033.8	5
6	.1000	296.6	1867.3	314.0	1922.8	332.0	1978.6	350.6	2034.7	6
7	.1167	296.9	1868.2	314.3	1923.7	332.3	1979.5	350.9	2035.6	7
8	.1333	297.2	1869.2	314.6	1924.7	332.6	1980.5	351.2	2036.6	8
9	.1500	297.5	1870.1	314.9	1925.6	332.9	1981.4	351.5	2037.5	9
10	.1667	297.7	1871.0	315.2	1926.5	333.2	1982.3	351.8	2038.5	10
11	.1833	298.0	1871.9	315.5	1927.4	333.5	1983.2	352.1	2039.4	11
12	.2000	298.3	1872.9	315.8	1928.4	333.8	1984.2	352.4	2040.4	12
13	.2167	298.6	1873.8	316.1	1929.3	334.2	1985.1	352.8	2041.3	13
14	.2333	298.9	1874.7	316.4	1930.2	334.5	1986.1	353.1	2042.3	14
15	.2500	299.2	1875.6	316.7	1931.1	334.8	1987.0	353.4	2043.2	15
16	.2667	299.5	1876.5	317.0	1932.1	335.1	1987.9	353.7	2044.1	16
17	.2833	299.7	1877.4	317.2	1933.0	335.4	1988.8	354.0	2045.0	17
18	.3000	300.0	1878.4	317.5	1933.9	335.7	1989.8	354.3	2046.0	18
19	.3167	300.3	1879.3	317.8	1934.8	336.0	1990.7	354.6	2046.9	19
20	.3333	300.6	1880.2	318.1	1935.8	336.3	1991.7	354.9	2047.9	20
21	.3500	300.9	1881.1	318.4	1936.7	336.6	1992.6	355.3	2048.8	21
22	.3667	301.2	1882.1	318.7	1937.6	336.9	1993.6	355.6	2049.8	22
23	.3833	301.5	1883.0	319.0	1938.5	337.2	1994.5	355.9	2050.7	23
24	.4000	301.8	1883.9	319.3	1939.5	337.5	1995.4	356.2	2051.7	24
25	.4167	302.0	1884.8	319.6	1940.4	337.8	1996.3	356.6	2052.6	25
26	.4333	302.3	1885.8	319.9	1941.3	338.1	1997.3	356.9	2053.5	26
27	.4500	302.6	1886.7	320.2	1942.2	338.4	1998.2	357.2	2054.4	27
28	.4667	302.9	1887.6	320.5	1943.2	338.7	1999.2	357.5	2055.4	28
29	.4833	303.2	1888.5	320.8	1944.1	339.1	2000.1	357.8	2056.3	29
30	.5000	303.5	1889.5	321.1	1945.0	339.4	2001.0	358.1	2057.3	30
31	.5167	303.8	1890.4	321.4	1945.9	339.7	2001.9	358.4	2058.2	31
32	.5333	304.1	1891.3	321.7	1946.9	340.0	2002.9	358.8	2059.2	32
33	.5500	304.3	1892.2	322.0	1947.8	340.3	2003.8	359.1	2060.1	33
34	.5667	304.6	1893.2	322.3	1948.8	340.6	2004.8	359.4	2061.1	34
35	.5833	304.9	1894.1	322.6	1949.7	340.9	2005.7	359.8	2062.0	35
36	.6000	305.2	1895.0	322.9	1950.6	341.2	2006.6	360.1	2063.0	36
37	.6167	305.5	1895.9	323.2	1951.5	341.5	2007.5	360.4	2063.9	37
38	.6333	305.8	1896.9	323.5	1952.5	341.8	2008.5	360.7	2064.8	38
39	.6500	306.1	1897.8	323.8	1953.4	342.1	2009.4	361.0	2065.7	39
40	.6667	306.4	1898.7	324.2	1954.4	342.4	2010.4	361.3	2066.7	40
41	.6833	306.7	1899.6	324.5	1955.3	342.8	2011.3	361.6	2067.6	41
42	.7000	307.0	1900.6	324.8	1956.2	343.1	2012.3	362.0	2068.6	42
43	.7167	307.2	1901.5	325.1	1957.1	343.4	2013.2	362.3	2069.5	43
44	.7333	307.5	1902.4	325.4	1958.1	343.7	2014.1	362.6	2070.5	44
45	.7500	307.8	1903.3	325.7	1959.0	344.0	2015.0	363.0	2071.4	45
46	.7667	308.1	1904.3	326.0	1960.0	344.3	2016.0	363.3	2072.4	46
47	.7833	308.4	1905.2	326.3	1960.9	344.6	2016.9	363.6	2073.3	47
48	.8000	308.7	1906.1	326.6	1961.8	344.9	2017.9	363.9	2074.2	48
49	.8167	309.0	1907.0	326.9	1962.7	345.3	2018.8	364.2	2075.1	49
50	.8333	309.3	1908.0	327.2	1963.7	345.6	2019.7	364.5	2076.1	50
51	.8500	309.6	1908.9	327.5	1964.6	345.9	2020.6	364.9	2077.0	51
52	.8667	309.9	1909.8	327.8	1965.5	346.2	2021.6	365.2	2078.0	52
53	.8833	310.2	1910.7	328.1	1966.4	346.5	2022.5	365.5	2078.9	53
54	.9000	310.5	1911.7	328.4	1967.4	346.8	2023.5	365.8	2079.9	54
55	.9167	310.8	1912.6	328.7	1968.3	347.1	2024.4	366.2	2080.8	55
56	.9333	311.1	1913.5	329.0	1969.3	347.4	2025.4	366.5	[illegible]	56
57	.9500	311.4	1914.4	329.3	1970.2	347.8	2026.3	366.8	[illegible]	57
58	.9667	311.7	1915.4	329.6	1971.1	348.1	2027.2	367.1	[illegible]	58
59	.9833	312.0	1916.3	329.9	1972.0	348.4	2028.1	367.4	[illegible]	59

100' Chords up to 8° Curves — Use 25' Chords up to 32° Curves
50' Chords up to 16° Curves — Use 10' Chords above 32° Curves

Degree	40° Ext.	40° Tan.	41° Ext.	41° Tan.	42° Ext.	42° Tan.	43° Ext.	43° Tan.	Minutes
00	367.7	2085.5	387.4	2142.3	407.7	2199.5	428.6	2257.1	0
67	368.0	2086.4	387.8	2143.2	408.0	2200.4	429.0	2258.0	1
33	368.4	2087.4	388.1	2144.2	408.3	2201.4	429.3	2259.0	2
00	368.7	2088.3	388.5	2145.1	408.7	2202.3	429.7	2260.0	3
67	369.0	2089.3	388.8	2146.1	409.0	2203.3	430.0	2261.0	4
33	369.4	2090.2	389.1	2147.0	409.4	2204.3	430.4	2261.9	5
00	369.7	2091.2	389.4	2148.0	409.7	2205.3	430.7	2262.9	6
67	370.0	2092.1	389.8	2148.9	410.1	2206.2	431.1	2263.8	7
33	370.3	2093.1	390.1	2149.9	410.4	2207.2	431.4	2264.8	8
00	370.7	2094.0	390.4	2150.9	410.8	2208.1	431.8	2265.7	9
67	371.0	2095.0	390.7	2151.9	411.1	2209.1	432.1	2266.7	10
33	371.3	2095.9	391.1	2152.8	411.5	2210.0	432.4	2267.7	11
00	371.6	2096.9	391.4	2153.8	411.8	2211.0	432.8	2268.7	12
67	372.0	2097.8	391.8	2154.7	412.2	2211.9	433.2	2269.6	13
33	372.3	2098.8	392.1	2155.7	412.5	2212.9	433.5	2270.6	14
00	372.6	2099.7	392.4	2156.6	412.9	2213.9	433.9	2271.5	15
67	372.9	2100.7	392.7	2157.6	413.2	2214.9	434.2	2272.5	16
33	373.3	2101.6	393.1	2158.5	413.6	2215.8	434.6	2273.5	17
00	373.6	2102.6	393.4	2159.5	413.9	2216.8	434.9	2274.5	18
67	374.0	2103.5	393.7	2160.4	414.3	2217.7	435.3	2275.4	19
33	374.3	2104.5	394.1	2161.4	414.6	2218.7	435.6	2276.4	20
00	374.6	2105.4	394.4	2162.3	415.0	2219.6	436.0	2277.3	21
67	374.9	2106.3	394.7	2163.3	415.3	2220.6	436.3	2278.3	22
33	375.3	2107.2	395.1	2164.2	415.7	2221.5	436.7	2279.2	23
00	375.6	2108.2	395.4	2165.2	416.0	2222.5	437.0	2280.2	24
67	375.9	2109.1	395.8	2166.1	416.3	2223.4	437.4	2281.2	25
33	376.2	2110.1	396.1	2167.1	416.6	2224.4	437.8	2282.2	26
00	376.6	2111.0	396.5	2168.0	417.0	2225.4	438.2	2283.1	27
67	376.9	2112.0	396.8	2169.0	417.3	2226.4	438.5	2284.1	28
33	377.2	2112.9	397.2	2169.9	417.7	2227.3	438.9	2285.0	29
00	377.5	2113.9	397.5	2170.9	418.0	2228.3	439.2	2286.0	30
67	377.9	2114.8	397.8	2171.8	418.4	2229.2	439.6	2287.0	31
33	378.2	2115.8	398.1	2172.8	418.7	2230.2	439.9	2288.0	32
00	378.5	2116.7	398.5	2173.7	419.1	2231.1	440.3	2288.9	33
67	378.8	2117.7	398.8	2174.7	419.4	2232.1	440.6	2289.9	34
33	379.1	2118.6	399.2	2175.6	419.8	2233.0	441.0	2290.8	35
00	379.5	2119.6	399.5	2176.6	420.1	2234.0	441.4	2291.8	36
67	379.8	2120.5	399.9	2177.5	420.5	2235.0	441.8	2292.8	37
3	380.1	2121.5	400.2	2178.5	420.8	2236.0	442.1	2293.8	38
0	380.5	2122.4	400.6	2179.4	421.2	2236.9	442.5	2294.7	39
7	380.8	2123.4	400.9	2180.4	421.5	2237.9	442.8	2295.7	40
3	381.1	2124.3	401.2	2181.4	421.9	2238.8	443.2	2296.7	41
0	381.4	2125.3	401.5	2182.4	422.2	2239.8	443.5	2297.7	42
7	381.8	2126.2	401.9	2183.3	422.6	2240.7	443.9	2298.6	43
3	382.1	2127.2	402.2	2184.3	422.9	2241.7	444.2	2299.6	44
0	382.5	2128.1	402.6	2185.2	423.3	2242.6	444.6	2300.5	45
7	382.8	2129.1	402.9	2186.2	423.6	2243.6	445.0	2301.5	46
3	383.1	2130.0	403.3	2187.1	424.0	2244.6	445.4	2302.5	47
0	383.4	2131.0	403.6	2188.1	424.3	2245.6	445.7	2303.5	48
7	383.8	2131.9	404.0	2189.0	424.7	2246.5	446.1	2304.4	49
3	384.1	2132.9	404.3	2190.0	425.0	2247.5	446.4	2305.4	50
0	384.5	2133.8	404.6	2190.9	425.4	2248.4	446.8	2306.3	51
7	384.8	2134.7	404.9	2191.9	425.7	2249.4	447.1	2307.3	52
3	385.1	2135.6	405.3	2192.8	426.1	2250.3	447.5	2308.3	53
0	385.4	2136.6	405.6	2193.8	426.4	2251.3	447.8	2309.3	54
7	385.8	2137.5	406.0	2194.7	426.8	2252.3	448.2	2310.3	55
3	386.1	2138.5	406.3	2195.7	427.1	2253.3	448.6	2311.2	56
	386.5	2139.4	406.7	2196.6	427.5	2254.2	449.0	2312.2	57
	386.8	2140.4	407.0	2197.6	427.8	2255.2	449.3	2313.2	58
	387.1	2141.3	407.4	2198.5	428.2	2256.1	449.7	2314.2	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	44° Ext.	44° Tan.	45° Ext.	45° Tan.	46° Ext.	46° Tan.	47° Ext.	47° Tan.	Minutes
0	.0000	450.0	2315.1	472.1	2373.4	494.8	2432.2	518.3	2491.5	0
1	.0167	450.4	2316.0	472.5	2374.4	495.2	2433.2	518.7	2492.4	1
2	.0333	450.7	2317.0	472.9	2375.4	495.6	2434.2	519.0	2493.4	2
3	.0500	451.1	2318.0	473.3	2376.3	496.0	2435.1	519.4	2494.4	3
4	.0667	451.5	2319.0	473.6	2377.3	496.4	2436.1	519.8	2495.4	4
5	.0833	451.9	2319.9	474.0	2378.3	496.7	2437.1	520.2	2496.4	5
6	.1000	452.2	2320.9	474.4	2379.3	497.2	2438.1	520.6	2497.4	6
7	.1167	452.6	2321.8	474.8	2380.2	497.6	2439.1	521.0	2498.4	7
8	.1333	452.9	2322.8	475.1	2381.2	497.9	2440.1	521.4	2499.4	8
9	.1500	453.3	2323.8	475.5	2382.2	498.3	2441.1	521.8	2500.4	9
10	.1667	453.7	2324.8	475.9	2383.2	498.7	2442.1	522.2	2501.4	10
11	.1833	454.1	2325.7	476.3	2384.2	499.1	2443.0	522.6	2502.4	11
12	.2000	454.4	2326.7	476.6	2385.2	499.5	2444.0	523.0	2503.4	12
13	.2167	454.8	2327.7	477.0	2386.1	499.9	2445.0	523.4	2504.4	13
14	.2333	455.1	2328.7	477.4	2387.1	500.3	2446.0	523.8	2505.4	14
15	.2500	455.5	2329.6	477.8	2388.1	500.7	2447.0	524.2	2506.3	15
16	.2667	455.9	2330.6	478.1	2389.1	501.0	2448.0	524.6	2507.3	16
17	.2833	456.3	2331.6	478.5	2390.0	501.4	2449.0	525.0	2508.3	17
18	.3000	456.6	2332.6	478.9	2391.0	501.8	2449.9	525.4	2509.3	18
19	.3167	457.0	2333.5	479.3	2392.0	502.2	2450.9	525.8	2510.3	19
20	.3333	457.3	2334.5	479.6	2393.0	502.6	2451.9	526.2	2511.3	20
21	.3500	457.7	2335.4	480.0	2393.9	503.0	2452.9	526.6	2512.3	21
22	.3667	458.1	2336.4	480.4	2394.9	503.4	2453.9	527.0	2513.3	22
23	.3833	458.5	2337.4	480.8	2395.9	503.8	2454.9	527.4	2514.3	23
24	.4000	458.8	2338.4	481.1	2396.9	504.1	2455.9	527.8	2515.3	24
25	.4167	459.2	2339.3	481.5	2397.8	504.5	2456.8	528.2	2516.3	25
26	.4333	459.5	2340.3	481.9	2398.8	504.9	2457.8	528.6	2517.3	26
27	.4500	459.9	2341.3	482.3	2399.8	505.3	2458.8	529.0	2518.3	27
28	.4667	460.3	2342.3	482.6	2400.8	505.7	2459.8	529.4	2519.3	28
29	.4833	460.7	2343.2	483.0	2401.8	506.1	2460.8	529.8	2520.2	29
30	.5000	461.0	2344.2	483.4	2402.8	506.5	2461.8	530.2	2521.2	30
31	.5167	461.4	2345.1	483.8	2403.7	506.9	2462.8	530.6	2522.2	31
32	.5333	461.7	2346.1	484.2	2404.7	507.3	2463.8	531.0	2523.2	32
33	.5500	462.1	2347.1	484.6	2405.7	507.7	2464.7	531.4	2524.2	33
34	.5667	462.5	2348.1	484.9	2406.7	508.0	2465.7	531.8	2525.2	34
35	.5833	462.9	2349.0	485.3	2407.6	508.4	2466.7	532.2	2526.2	35
36	.6000	463.2	2350.0	485.7	2408.6	508.8	2467.7	532.6	2527.2	36
37	.6167	463.6	2351.0	486.1	2409.6	509.2	2468.7	533.0	2528.2	37
38	.6333	463.9	2352.0	486.5	2410.6	509.6	2469.7	533.4	2529.2	38
39	.6500	464.3	2352.9	486.9	2411.6	510.0	2470.7	533.8	2530.2	39
40	.6667	464.7	2353.9	487.2	2412.6	510.4	2471.7	534.2	2531.2	40
41	.6833	465.0	2354.9	487.6	2413.5	510.8	2472.6	534.6	2532.2	41
42	.7000	465.4	2355.9	488.0	2414.5	511.1	2473.6	535.0	2533.2	42
43	.7167	465.8	2356.8	488.4	2415.5	511.5	2474.6	535.4	2534.2	43
44	.7333	466.2	2357.8	488.7	2416.5	511.9	2475.6	535.8	2535.2	44
45	.7500	466.5	2358.8	489.1	2417.5	512.3	2476.6	536.2	2536.2	45
46	.7667	466.9	2359.8	489.5	2418.5	512.7	2477.6	536.6	2537.2	46
47	.7833	467.3	2360.7	489.9	2419.4	513.1	2478.6	537.0	2538.2	47
48	.8000	467.7	2361.7	490.3	2420.4	513.5	2479.6	537.4	2539.2	48
49	.8167	468.0	2362.7	490.7	2421.4	513.9	2480.6	537.8	2540.2	49
50	.8333	468.4	2363.7	491.0	2422.4	514.3	2481.6	538.2	2541.2	50
51	.8500	468.8	2364.6	491.4	2423.4	514.7	2482.5	538.6	2542.2	51
52	.8667	469.1	2365.6	491.8	2424.4	515.1	2483.5	539.0	2543.2	52
53	.8833	469.5	2366.6	492.2	2425.3	515.5	2484.5	539.4	2544.2	53
54	.9000	469.9	2367.6	492.5	2426.3	515.9	2485.5	539.8	2545.2	54
55	.9167	470.3	2368.5	492.9	2427.3	516.3	2486.5	540.2	2546.2	55
56	.9333	470.6	2369.5	493.3	2428.3	516.7	2487.5	540.6	2547.2	56
57	.9500	471.0	2370.5	493.7	2429.2	517.1	2488.5	541.0	2548.2	57
58	.9667	471.4	2371.5	494.1	2430.2	517.5	2489.5	541.4	2549.2	58
59	.9833	471.8	2372.4	494.5	2431.2	517.9	2490.5	541.8	2550.2	59

Use 100' Chords up to 8° Curves — Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves — Use 10' Chords above 32° Curves

Dec. of Degree	48°		49°		50°		51°		Minutes
	Ext	Tan	Ext.	Tan.	Ext.	Tan.	Ext.	Tan	
.0000	542.3	2551.1	567.0	2611.3	592.4	2671.9	618.5	2733.0	0
.0167	542.7	2552.1	567.4	2612.3	592.8	2672.9	618.9	2734.1	1
.0333	543.1	2553.1	567.8	2613.3	593.2	2673.9	619.3	2735.1	2
.0500	543.5	2554.1	568.3	2614.3	593.7	2675.0	619.8	2736.1	3
.0667	543.9	2555.1	568.7	2615.3	594.1	2676.0	620.2	2737.1	4
.0833	544.3	2556.1	569.1	2616.3	594.5	2677.0	620.7	2738.2	5
.1000	544.7	2557.1	569.5	2617.3	594.9	2678.0	621.1	2739.2	6
.1167	545.1	2558.1	569.9	2618.3	595.4	2679.0	621.6	2740.2	7
.1333	545.5	2559.1	570.3	2619.3	595.8	2680.0	622.0	2741.2	8
.1500	546.0	2560.1	570.8	2620.4	596.2	2681.1	622.5	2742.3	9
.1667	546.4	2561.1	571.2	2621.4	596.7	2682.1	622.9	2743.3	10
.1833	546.8	2562.1	571.6	2622.4	597.1	2683.1	623.3	2744.3	11
.2000	547.2	2563.1	572.0	2623.4	597.5	2684.1	623.7	2745.3	12
.2167	547.6	2564.1	572.4	2624.4	598.0	2685.1	624.2	2746.4	13
.2333	548.0	2565.1	572.8	2625.4	598.4	2686.1	624.6	2747.4	14
.2500	548.4	2566.1	573.3	2626.4	598.9	2687.2	625.1	2748.4	15
.2667	548.8	2567.1	573.7	2627.4	599.3	2688.2	625.5	2749.4	16
.2833	549.2	2568.1	574.1	2628.4	599.7	2689.2	626.0	2750.5	17
.3000	549.6	2569.1	574.5	2629.4	600.1	2690.2	626.4	2751.5	18
.3167	550.1	2570.1	574.9	2630.4	600.6	2691.3	626.9	2752.5	19
.3333	550.5	2571.1	575.3	2631.4	601.0	2692.3	627.3	2753.5	20
.3500	550.9	2572.1	575.8	2632.5	601.5	2693.3	627.8	2754.6	21
.3667	551.3	2573.1	576.2	2633.5	601.9	2694.3	628.2	2755.6	22
.3833	551.7	2574.1	576.6	2634.5	602.3	2695.3	628.7	2756.7	23
.4000	552.1	2575.1	577.0	2635.5	602.7	2696.3	629.1	2757.7	24
.4167	552.5	2576.1	577.5	2636.5	603.2	2697.4	629.6	2758.7	25
.4333	552.9	2577.1	577.9	2637.5	603.6	2698.4	630.0	2759.7	26
.4500	553.3	2578.1	578.3	2638.5	604.1	2699.4	630.5	2760.8	27
.4667	553.7	2579.1	578.7	2639.5	604.5	2700.4	630.9	2761.8	28
.4833	554.2	2580.1	579.2	2640.5	604.9	2701.4	631.4	2762.8	29
.5000	554.6	2581.1	579.6	2641.5	605.3	2702.4	631.8	2763.8	30
.5167	555.0	2582.1	580.0	2642.5	605.8	2703.5	632.3	2764.9	31
.5333	555.4	2583.1	580.4	2643.5	606.2	2704.5	632.7	2765.9	32
.5500	555.8	2584.1	580.9	2644.6	606.6	2705.5	633.2	2766.9	33
.5667	556.2	2585.1	581.3	2645.6	607.0	2706.5	633.6	2767.9	34
.5833	556.6	2586.2	581.7	2646.6	607.5	2707.6	634.1	2769.0	35
.6000	557.0	2587.2	582.1	2647.6	607.9	2708.6	634.5	2770.0	36
.6167	557.4	2588.2	582.6	2648.6	608.4	2709.6	634.9	2771.0	37
.6333	557.8	2589.2	583.0	2649.6	608.8	2710.6	635.3	2772.0	38
.6500	558.3	2590.2	583.4	2650.6	609.3	2711.6	635.8	2773.1	39
.6667	558.7	2591.2	583.8	2651.6	609.7	2712.6	636.2	2774.1	40
.6833	559.1	2592.2	584.3	2652.7	610.1	2713.7	636.7	2775.2	41
.7000	559.5	2593.2	584.7	2653.7	610.5	2714.7	637.1	2776.2	42
.7167	559.9	2594.2	585.1	2654.7	611.0	2715.7	637.5	2777.2	43
.7333	560.3	2595.2	585.5	2655.7	611.4	2716.7	638.0	2778.2	44
.7500	560.8	2596.2	586.0	2656.7	611.9	2717.8	638.5	2779.3	45
.7667	561.2	2597.2	586.4	2657.7	612.3	2718.8	638.9	2780.3	46
.7833	561.6	2598.2	586.8	2658.7	612.8	2719.8	639.4	2781.3	47
.8000	562.0	2599.2	587.2	2659.7	613.2	2720.8	639.9	2782.3	48
.8167	562.4	2600.2	587.7	2660.8	613.7	2721.8	640.3	2783.3	49
.8333	562.8	2601.2	588.1	2661.8	614.1	2722.8	640.7	2784.4	50
.8500	563.3	2602.2	588.5	2662.8	614.5	2723.9	641.2	2785.4	51
.8667	563.7	2603.2	588.9	2663.8	614.9	2724.9	641.6	2786.4	52
.8833	564.1	2604.2	589.4	2664.8	615.4	2725.9	642.1	2787.5	53
.9000	564.5	2605.2	589.8	2665.8	615.8	2726.9	642.5	2788.5	54
.9167	564.9	2606.2	590.2	2666.8	616.3	2728.0	643.0	2789.6	55
.9333	565.3	2607.2	590.6	2667.8	616.7	2729.0	643.4	2790.6	56
.9500	565.8	2608.3	591.1	2668.9	617.2	2730.0	643.9	2791.6	57
.9667	566.2	2609.3	591.5	2669.9	617.6	2731.0	644.3	2792.6	58
.9833	566.6	2610.3	592.0	2670.9	618.1	2732.0	644.8	2793.7	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	52°		53°		54°		55°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	645.2	2794.7	672.7	2856.9	700.9	2919.5	729.9	2982.8	0
1	.0167	645.7	2795.8	673.2	2857.9	701.4	2920.6	730.4	2983.9	1
2	.0333	646.1	2796.8	673.7	2858.9	701.9	2921.6	730.9	2984.9	2
3	.0500	646.6	2797.8	674.2	2860.0	702.4	2922.7	731.4	2986.0	3
4	.0667	647.0	2798.8	674.6	2861.0	702.8	2923.8	731.9	2987.1	4
5	.0833	647.5	2799.9	675.1	2862.1	703.3	2924.9	732.4	2988.2	5
6	.1000	647.9	2800.9	675.5	2863.1	703.8	2925.9	732.9	2989.2	6
7	.1167	648.4	2802.0	676.0	2864.2	704.3	2927.0	733.4	2990.3	7
8	.1333	648.9	2803.0	676.4	2865.2	704.8	2928.0	733.8	2991.3	8
9	.1500	649.4	2804.0	676.9	2866.3	705.3	2929.1	734.3	2992.4	9
10	.1667	649.8	2805.0	677.4	2867.3	705.7	2930.1	734.8	2993.4	10
11	.1833	650.3	2806.1	677.9	2868.4	706.2	2931.2	735.3	2994.5	11
12	.2000	650.7	2807.1	678.3	2869.4	706.7	2932.2	735.8	2995.5	12
13	.2167	651.2	2808.2	678.8	2870.5	707.2	2933.3	736.3	2996.6	13
14	.2333	651.6	2809.2	679.2	2871.5	707.7	2934.3	736.8	2997.7	14
15	.2500	652.1	2810.2	679.7	2872.5	708.2	2935.4	737.3	2998.8	15
16	.2667	652.5	2811.2	680.2	2873.5	708.6	2936.4	737.8	2999.8	16
17	.2833	653.0	2812.3	680.7	2874.6	709.1	2937.5	738.2	3000.9	17
18	.3000	653.4	2813.3	681.1	2875.6	709.6	2938.5	738.7	3001.9	18
19	.3167	653.9	2814.4	681.6	2876.7	710.1	2939.6	739.2	3003.0	19
20	.3333	654.3	2815.4	682.0	2877.7	710.5	2940.6	739.7	3004.0	20
21	.3500	654.8	2816.4	682.5	2878.8	711.0	2941.7	740.2	3005.1	21
22	.3667	655.2	2817.4	683.0	2879.8	711.5	2942.7	740.7	3006.2	22
23	.3833	655.7	2818.5	683.5	2880.9	712.0	2943.8	741.2	3007.3	23
24	.4000	656.2	2819.5	683.9	2881.9	712.5	2944.8	741.7	3008.3	24
25	.4167	656.7	2820.6	684.4	2883.0	713.0	2945.9	742.2	3009.4	25
26	.4333	657.1	2821.6	684.9	2884.0	713.4	2946.9	742.7	3010.4	26
27	.4500	657.6	2822.6	685.4	2885.1	713.9	2948.0	743.2	3011.5	27
28	.4667	658.0	2823.6	685.8	2886.1	714.4	2949.0	743.7	3012.5	28
29	.4833	658.5	2824.7	686.3	2887.1	714.9	2950.1	744.2	3013.6	29
30	.5000	658.9	2825.7	686.7	2888.1	715.3	2951.1	744.7	3014.7	30
31	.5167	659.4	2826.8	687.2	2889.2	715.8	2952.2	745.2	3015.8	31
32	.5333	659.8	2827.8	687.7	2890.2	716.3	2953.2	745.7	3016.8	32
33	.5500	660.3	2828.8	688.2	2891.3	716.8	2954.3	746.2	3017.9	33
34	.5667	660.7	2829.8	688.6	2892.3	717.3	2955.3	746.7	3018.9	34
35	.5833	661.2	2830.9	689.1	2893.4	717.8	2956.4	747.2	3020.0	35
36	.6000	661 6	2831.9	689.6	2894.4	718.2	2957.5	747.7	3021.1	36
37	.6167	662.1	2833.0	690.1	2895.5	718.7	2958.6	748.2	3022.1	37
38	.6333	662.5	2834.0	690.5	2896.5	719.2	2959.6	748.7	3023.2	38
39	.6500	663.0	2835.1	691.0	2897.6	719.7	2960.7	749.2	3024.3	39
40	.6667	663.5	2836.1	691.5	2898.6	720.2	2961.7	749.7	3025.3	40
41	.6833	664.0	2837.2	692.0	2899.7	720.7	2962.8	750.2	3026.4	41
42	.7000	664.4	2838.2	692.4	2900.7	721.1	2963.8	750.7	3027.5	42
43	.7167	664.9	2839.2	692.9	2901.8	721.6	2964.9	751.2	3028.6	43
44	.7333	665.3	2840.2	693.4	2902.8	722.1	2965.9	751.7	3029.6	44
45	.7500	665.8	2841.3	693.9	2903.9	722.6	2967.0	752.2	3030.7	45
46	.7667	666.2	2842.3	694.3	2904.9	723.1	2968.0	752.6	3031.7	46
47	.7833	666.7	2843.4	694.8	2906.0	723.6	2969.1	753.1	3032.8	47
48	.8000	667.2	2844.4	695.3	2907.0	724.1	2970.1	753.6	3033.8	48
49	.8167	667.7	2845.5	695.8	2908.1	724.6	2971.2	754.1	3035.0	49
50	.8333	668.1	2846.5	696.2	2909.1	725.0	2972.2	754.6	3036.0	50
51	.8500	668.6	2847.5	696.7	2910.2	725.5	2973.3	755.1	3037.1	51
52	.8667	669.0	2848.5	697.1	2911.2	726.0	2974.4	755.6	3038.1	52
53	.8833	669.5	2849.6	697.6	2912.3	726.5	2975.5	756.1	3039.2	53
54	.9000	669.9	2850.6	698.1	2913.3	727.0	2976.5	756.6	3040.2	54
55	.9167	670.4	2851.7	698.6	2914.4	727.5	2977.6	757.1	3041.3	55
56	.9333	670.9	2852.7	699.0	2915.4	728.0	2978.6	757.6	3042.4	56
57	.9500	671.4	2853.8	699.5	2916.5	728.5	2979.7	758.1	[illegible]	57
58	.9667	6 1.8	2854.8	700.0	2917.5	729.0	2980.7	758.6	[illegible]	58
59	.9833	672.3	2855.9	700.5	2918.5	729.5	2981.8	[illegible]	[illegible]	59

100' Chords up to 8° Curves Use 25' Chords up to 32° Curves
50' Chords up to 16° Curves Use 10' Chords above 32° Curves

Degree	56° Ext.	56° Tan.	57° Ext.	57° Tan.	58° Ext.	58° Tan.	59° Ext.	59° Tan.	Minutes
00	759.6	3046.6	790.2	3111.1	821.4	3176.1	853.5	3241.9	0
67	760.1	3047.7	790.7	3112.2	822.0	3177.2	854.0	3243.0	1
33	760.6	3048.8	791.2	3113.3	822.5	3178.3	854.6	3244.1	2
00	761.1	3049.9	791.7	3114.4	823.0	3179.4	855.1	3245.2	3
67	761.6	3050.9	792.2	3115.4	823.5	3180.5	855.7	3246.3	4
33	762.2	3052.0	792.8	3116.5	824.1	3181.6	856.2	3247.4	5
00	762.7	3053.1	793.3	3117.6	824.6	3182.7	856.8	3248.5	6
67	763.2	3054.2	793.8	3118.7	825.2	3183.8	857.3	3249.6	7
33	763.7	3055.2	794.3	3119.7	825.7	3184.9	857.9	3250.7	8
00	764.2	3056.3	794.8	3120.8	826.2	3186.0	858.5	3251.8	9
67	764.7	3057.4	795.3	3121.9	826.7	3187.1	859.0	3252.9	10
33	765.2	3058.5	795.8	3123.0	827.3	3188.2	859.5	3254.0	11
00	765.7	3059.5	796.3	3124.1	827.8	3189.2	860.0	3255.1	12
67	766.2	3060.6	796.9	3125.2	828.4	3190.3	860.6	3256.2	13
33	766.7	3061.6	797.4	3126.2	828.9	3191.4	861.1	3257.3	14
00	767.2	3062.7	797.9	3127.3	829.4	3192.5	861.7	3258.4	15
67	767.7	3063.8	798.4	3128.4	829.9	3193.6	862.2	3259.5	16
33	768.2	3064.9	798.9	3129.5	830.5	3194.7	862.8	3260.6	17
00	768.7	3065.9	799.4	3130.6	831.0	3195.8	863.3	3261.7	18
67	769.2	3067.0	799.9	3131.7	831.5	3196.9	863.8	3262.8	19
33	769.7	3068.1	800.5	3132.7	832.1	3198.0	864.4	3263.9	20
00	770.3	3069.2	801.0	3133.8	832.5	3199.1	864.9	3265.0	21
67	770.8	3070.2	801.5	3134.9	833.1	3200.2	865.5	3266.1	22
33	771.3	3071.3	802.0	3136.0	833.6	3201.3	866.0	3267.2	23
00	771.8	3072.4	802.5	3137.0	834.2	3202.4	866.6	3268.3	24
67	772.3	3073.5	803.1	3138.1	834.7	3203.5	867.1	3269.4	25
33	772.8	3074.5	803.6	3139.2	835.3	3204.5	867.7	3270.5	26
00	773.3	3075.6	804.2	3140.3	835.8	3205.6	868.2	3271.6	27
67	773.8	3076.6	804.7	3141.4	836.3	3206.7	868.8	3272.7	28
33	774.3	3077.7	805.2	3142.5	836.8	3207.8	869.3	3273.8	29
00	774.8	3078.8	805.7	3143.5	837.4	3208.9	869.9	3274.9	30
67	775.3	3079.9	806.3	3144.6	837.9	3210.0	870.5	3276.0	31
33	775.8	3080.9	806.8	3145.7	838.4	3211.1	871.0	3277.1	32
00	776.3	3082.0	807.3	3146.8	838.9	3212.2	871.6	3278.2	33
67	776.8	3083.1	807.8	3147.9	839.5	3213.3	872.1	3279.4	34
33	777.3	3084.2	808.3	3149.0	840.0	3214.4	872.7	3280.5	35
00	777.8	3085.2	808.8	3150.0	840.6	3215.5	873.2	3281.6	36
67	778.4	3086.3	809.4	3151.1	841.1	3216.6	873.8	3282.7	37
33	778.9	3087.4	809.9	3152.2	841.6	3217.7	874.3	3283.8	38
00	779.4	3088.5	810.4	3153.3	842.1	3218.8	874.9	3284.9	39
67	779.9	3089.6	810.9	3154.4	842.7	3219.9	875.4	3286.0	40
33	780.4	3090.7	811.5	3155.5	843.1	3221.0	876.0	3287.1	41
00	780.9	3091.7	812.0	3156.6	843.8	3222.1	876.5	3288.2	42
67	781.4	3092.8	812.5	3157.7	844.3	3223.2	877.0	3289.3	43
33	781.9	3093.9	813.0	3158.7	844.9	3224.3	877.6	3290.5	44
00	782.5	3095.0	813.6	3159.8	845.5	3225.4	878.1	3291.6	45
67	783.0	3096.0	814.1	3160.9	846.0	3226.5	878.7	3292.7	46
33	783.5	3097.1	814.6	3162.0	846.5	3227.6	879.2	3293.8	47
00	784.0	3098.2	815.1	3163.1	847.0	3228.7	879.8	3294.9	48
67	784.5	3099.3	815.7	3164.2	847.6	3229.8	880.3	3296.0	49
33	785.0	3100.3	816.2	3165.3	848.1	3230.9	880.9	3297.1	50
00	785.5	3101.4	816.7	3166.4	848.7	3232.0	881.5	3298.2	51
67	786.0	3102.5	817.2	3167.4	849.2	3233.1	882.0	3299.3	52
33	786.6	3103.6	817.8	3168.5	849.8	3234.2	882.6	3300.4	53
00	787.1	3104.6	818.3	3169.6	850.3	3235.3	883.1	3301.5	54
67	787.6	3105.7	818.8	3170.7	850.9	3236.4	883.7	3302.6	55
33	788.1	3106.8	819.3	3171.8	851.4	3237.5	884.2	3303.8	56
00	788.6	3107.9	819.9	3172.9	852.0	3238.6	884.8	3304.9	57
67	789.1	3108.9	820.4	3174.0	852.5	3239.7	885.3	3306.0	58
33	789.7	3110.0	820.9	3175.1	853.0	3240.8	885.9	3307.1	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	60° Ext.	60° Tan.	61° Ext.	61° Tan.	62° Ext.	62° Tan.	63° Ext.	63° Tan.	Minutes
0	.0000	886.4	3308.2	920.2	3375.7	954.8	3442.9	990.3	3511.3	0
1	.0167	886.9	3309.3	920.8	3376.8	955.3	3444.1	990.9	3512.4	1
2	.0333	887.5	3310.4	921.4	3377.9	956.0	3445.2	991.5	3513.6	2
3	.0500	888.1	3311.5	922.0	3378.5	956.6	3446.3	992.1	3514.8	3
4	.0667	888.7	3312.7	922.5	3379.7	957.2	3447.5	992.7	3515.9	4
5	.0833	889.3	3313.8	923.0	3380.8	957.7	3448.6	993.3	3517.1	5
6	.1000	889.8	3314.9	923.6	3381.9	958.3	3449.7	993.9	3518.2	6
7	.1167	890.4	3316.0	924.2	3383.1	958.9	3450.9	994.5	3519.3	7
8	.1333	890.9	3317.1	924.8	3384.2	959.5	3452.0	995.1	3520.5	8
9	.1500	891.5	3318.2	925.3	3385.3	960.1	3453.2	995.7	3521.6	9
10	.1667	892.0	3319.3	925.9	3386.4	960.7	3454.3	996.3	3522.8	10
11	.1833	892.6	3320.5	926.5	3387.5	961.3	3455.4	996.9	3524.0	11
12	.2000	893.1	3321.6	927.1	3388.7	961.9	3456.6	997.5	3525.1	12
13	.2167	893.7	3322.7	927.6	3389.8	962.4	3457.7	998.1	3526.2	13
14	.2333	894.3	3323.8	928.2	3390.9	963.0	3458.8	998.7	3527.4	14
15	.2500	894.8	3324.9	928.7	3392.1	963.6	3460.0	999.3	3528.6	15
16	.2667	895.4	3326.0	929.3	3393.2	964.2	3461.1	999.9	3529.7	16
17	.2833	895.9	3327.1	929.9	3394.3	964.8	3462.3	1000.5	3530.9	17
18	.3000	896.5	3328.3	930.5	3395.4	965.4	3463.4	1001.1	3532.0	18
19	.3167	897.0	3329.4	931.0	3396.6	966.0	3464.6	1001.7	3533.1	19
20	.3333	897.6	3330.5	931.6	3397.7	966.6	3465.7	1002.3	3534.3	20
21	.3500	898.2	3331.6	932.2	3398.8	967.2	3466.8	1002.9	3535.4	21
22	.3667	898.8	3332.7	932.8	3400.0	967.8	3467.9	1003.5	3536.6	22
23	.3833	899.3	3333.8	933.3	3401.1	968.3	3469.0	1004.1	3537.8	23
24	.4000	899.9	3334.9	933.9	3402.2	968.9	3470.2	1004.7	3538.9	24
25	.4167	900.5	3336.1	934.5	3403.3	969.5	3471.3	1005.3	3540.0	25
26	.4333	901.0	3337.2	935.1	3404.4	970.1	3472.5	1005.9	3541.2	26
27	.4500	901.6	3338.3	935.7	3405.6	970.7	3473.6	1006.5	3542.3	27
28	.4667	902.1	3339.4	936.3	3406.7	971.3	3474.7	1007.1	3543.5	28
29	.4833	902.7	3340.5	936.8	3407.8	971.9	3475.9	1007.8	3544.6	29
30	.5000	903.3	3341.6	937.4	3408.9	972.5	3477.0	1008.4	3545.8	30
31	.5167	903.8	3342.7	938.0	3410.1	973.0	3478.1	1009.0	3546.9	31
32	.5333	904.4	3343.9	938.6	3411.2	973.6	3479.3	1009.6	3548.1	32
33	.5500	904.9	3345.0	939.1	3412.3	974.2	3480.5	1010.2	3549.2	33
34	.5667	905.5	3346.1	939.7	3413.5	974.8	3481.6	1010.8	3550.4	34
35	.5833	906.1	3347.2	940.4	3414.6	975.4	3482.7	1011.4	3551.6	35
36	.6000	906.6	3348.3	940.9	3415.7	976.0	3483.9	1012.0	3552.7	36
37	.6167	907.2	3349.5	941.5	3416.8	976.6	3485.0	1012.6	3553.8	37
38	.6333	907.7	3350.6	942.1	3418.0	977.2	3486.2	1013.2	3555.0	38
39	.6500	908.2	3351.7	942.6	3419.2	977.8	3487.4	1013.9	3556.2	39
40	.6667	908.8	3352.8	943.2	3420.3	978.4	3488.5	1014.5	3557.3	40
41	.6833	909.4	3354.0	943.8	3421.4	979.0	3489.6	1015.1	3558.4	41
42	.7000	910.0	3355.1	944.4	3422.5	979.6	3490.7	1015.7	3559.6	42
43	.7167	910.6	3356.2	945.0	3423.6	980.2	3491.9	1016.3	3560.8	43
44	.7333	911.1	3357.3	945.5	3424.8	980.8	3493.0	1016.9	3562.0	44
45	.7500	911.7	3358.4	946.1	3426.0	981.4	3494.2	1017.5	3563.2	45
46	.7667	912.3	3359.5	946.7	3427.1	982.0	3495.3	1018.1	3564.3	46
47	.7833	912.8	3360.6	947.2	3428.2	982.6	3496.4	1018.7	3565.5	47
48	.8000	913.4	3361.8	947.8	3429.3	983.2	3497.6	1019.3	3566.6	48
49	.8167	914.0	3362.9	948.4	3430.4	983.8	3498.7	1020.0	3567.7	49
50	.8333	914.5	3364.0	949.0	3431.6	984.4	3499.9	1020.6	3568.9	50
51	.8500	915.1	3365.1	949.6	3432.8	984.9	3501.0	1021.2	3570.0	51
52	.8667	915.7	3366.2	950.2	3433.9	985.5	3502.2	1021.8	3571.2	52
53	.8833	916.2	3367.3	950.7	3435.0	986.1	3503.3	1022.4	3572.3	53
54	.9000	916.8	3368.5	951.3	3436.1	986.7	3504.5	1023.0	3573.5	54
55	.9167	917.4	3369.6	951.9	3437.2	987.3	3505.6	1023.6	3574.6	55
56	.9333	918.0	3370.7	952.5	3438.4	987.9	3506.8	1024.2	[illegible]	56
57	.9500	918.6	3371.9	953.0	3439.6	988.5	3507.9	1024.8	[illegible]	57
58	.9667	919.1	3373.0	953.6	3440.7	989.1	3509.0	[illegible]	[illegible]	58
59	.9833	919.6	3374.2	954.3	3441.8	989.7	3510.1	[illegible]	[illegible]	59

Use 100' Chords up to 8° Curves — Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves — Use 10' Chords above 32° Curves

Minutes	Dec. of Degree	64° Ext.	64° Tan.	65° Ext.	65° Tan.	66° Ext.	66° Tan.	67° Ext.	67° Tan.	Minutes
0	.0000	1026.7	3580.4	1064.0	3650.4	1102.2	3721.1	1141.5	3792.6	0
1	.0167	1027.3	3581.6	1064.6	3651.6	1102.9	3722.3	1142.2	3793.8	1
2	.0333	1027.9	3582.8	1065.2	3652.8	1103.5	3723.4	1142.8	3795.0	2
3	.0500	1028.6	3584.0	1065.9	3654.0	1104.2	3724.6	1143.5	3796.2	3
4	.0667	1029.2	3585.1	1066.5	3655.1	1104.8	3725.8	1144.1	3797.4	4
5	.0833	1029.8	3586.3	1067.1	3656.3	1105.5	3727.0	1144.8	3798.6	5
6	.1000	1030.4	3587.4	1067.7	3657.5	1106.1	3728.2	1145.4	3799.8	6
7	.1167	1031.1	3588.6	1068.4	3658.6	1106.8	3729.4	1146.1	3801.0	7
8	.1333	1031.7	3589.7	1069.0	3659.8	1107.4	3730.6	1146.7	3802.2	8
9	.1500	1032.3	3590.9	1069.6	3661.0	1108.1	3731.7	1147.4	3803.4	9
10	.1667	1032.9	3592.1	1070.2	3662.2	1108.7	3733.0	1148.1	3804.6	10
11	.1833	1033.5	3593.3	1070.9	3663.4	1109.4	3734.1	1148.8	3805.8	11
12	.2000	1034.1	3594.4	1071.5	3664.5	1110.0	3735.3	1149.4	3807.0	12
13	.2167	1034.8	3595.5	1072.1	3665.7	1110.7	3736.5	1150.1	3808.2	13
14	.2333	1035.4	3596.7	1072.7	3666.9	1111.3	3737.7	1150.7	3809.4	14
15	.2500	1036.0	3597.9	1073.4	3668.0	1112.0	3738.9	1151.4	3810.6	15
16	.2667	1036.6	3599.1	1074.0	3669.2	1112.6	3740.1	1152.0	3811.8	16
17	.2833	1037.3	3600.3	1074.6	3670.4	1113.3	3741.3	1152.7	3813.0	17
18	.3000	1037.9	3601.4	1075.2	3671.6	1113.9	3742.4	1153.3	3814.2	18
19	.3167	1038.5	3602.6	1075.9	3672.8	1114.6	3743.6	1154.0	3815.4	19
20	.3333	1039.1	3603.7	1076.6	3673.9	1115.2	3744.8	1154.7	3816.6	20
21	.3500	1039.7	3604.8	1077.2	3675.0	1115.9	3746.0	1155.4	3817.8	21
22	.3667	1040.3	3606.0	1077.8	3676.2	1116.5	3747.2	1156.0	3819.0	22
23	.3833	1041.0	3607.1	1078.5	3677.4	1117.2	3748.4	1156.7	3820.2	23
24	.4000	1041.6	3608.4	1079.1	3678.6	1117.8	3749.6	1157.4	3821.4	24
25	.4167	1042.2	3609.5	1079.8	3679.7	1118.5	3750.7	1158.1	3822.6	25
26	.4333	1042.8	3610.7	1080.4	3680.9	1119.1	3751.9	1158.7	3823.8	26
27	.4500	1043.5	3611.9	1081.1	3682.1	1119.8	3753.1	1159.4	3825.0	27
28	.4667	1044.1	3613.0	1081.7	3683.3	1120.4	3754.3	1160.1	3826.2	28
29	.4833	1044.7	3614.1	1082.4	3684.5	1121.1	3755.5	1160.8	3827.4	29
30	.5000	1045.3	3615.3	1083.0	3685.6	1121.7	3756.7	1161.4	3828.6	30
31	.5167	1045.9	3616.5	1083.6	3686.8	1122.4	3757.9	1162.1	3829.8	31
32	.5333	1046.5	3617.7	1084.2	3688.0	1123.0	3759.1	1162.8	3831.0	32
33	.5500	1047.2	3618.9	1084.9	3689.2	1123.7	3760.3	1163.5	3832.2	33
34	.5667	1047.8	3620.0	1085.5	3690.4	1124.3	3761.5	1164.1	3833.4	34
35	.5833	1048.4	3621.1	1086.2	3691.6	1125.0	3762.7	1164.8	3834.6	35
36	.6000	1049.0	3622.3	1086.8	3692.7	1125.6	3763.9	1165.5	3835.9	36
37	.6167	1049.7	3623.5	1087.5	3694.0	1126.3	3765.1	1166.2	3837.1	37
38	.6333	1050.3	3624.7	1088.1	3695.1	1126.9	3766.3	1166.8	3838.3	38
39	.6500	1050.9	3625.8	1088.8	3696.3	1127.6	3767.5	1167.5	3839.5	39
40	.6667	1051.5	3627.0	1089.4	3697.4	1128.3	3768.7	1168.2	3840.7	40
41	.6833	1052.1	3628.2	1090.0	3698.6	1129.0	3769.9	1168.9	3841.9	41
42	.7000	1052.7	3629.4	1090.6	3699.8	1129.6	3771.0	1169.5	3843.1	42
43	.7167	1053.4	3630.5	1091.3	3701.0	1130.2	3772.2	1170.2	3844.3	43
44	.7333	1054.0	3631.7	1091.9	3702.2	1130.9	3773.4	1170.9	3845.5	44
45	.7500	1054.6	3632.8	1092.6	3703.4	1131.6	3774.6	1171.6	3846.7	45
46	.7667	1055.2	3634.0	1093.2	3704.5	1132.2	3775.8	1172.2	3847.9	46
47	.7833	1055.9	3635.2	1093.9	3705.7	1132.9	3777.0	1172.9	3849.1	47
48	.8000	1056.5	3636.4	1094.5	3706.9	1133.5	3778.2	1173.6	3850.4	48
49	.8167	1057.1	3637.5	1095.2	3708.1	1134.2	3779.4	1174.3	3851.6	49
50	.8333	1057.7	3638.7	1095.8	3709.3	1134.9	3780.6	1174.9	3852.8	50
51	.8500	1058.4	3639.9	1096.4	3710.5	1135.6	3781.8	1175.6	3854.0	51
52	.8667	1059.0	3641.1	1097.0	3711.6	1136.2	3783.0	1176.3	3855.2	52
53	.8833	1059.6	3642.3	1097.7	3712.8	1136.9	3784.2	1177.0	3856.4	53
54	.9000	1060.2	3643.4	1098.3	3714.0	1137.5	3785.4	1177.6	3857.6	54
55	.9167	1060.9	3644.6	1099.0	3715.2	1138.2	3786.6	1178.3	3858.8	55
56	.9333	1061.5	3645.7	1099.6	3716.4	1138.8	3787.8	1179.0	3860.0	56
57	.9500	1062.1	3646.9	1100.3	3717.5	1139.5	3789.0	1179.7	3861.[illegible]	57
58	.9667	1062.7	3648.1	1100.9	3718.7	1140.1	3790.2	1180.3	3862.[illegible]	58
59	.9833	1063.4	3649.2	1101.6	3720.0	1140.8	3791.4	1181.0	3863[illegible]	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec of Degree	68° Ext.	68° Tan.	69° Ext.	69° Tan.	70° Ext.	70° Tan.	71° Ext.	71° Tan.	Minutes
0	.0000	1181.6	3864.0	1222.9	3938.1	1265.0	4012.1	1308.4	4087.1	0
1	.0167	1182.3	3866.1	1223.6	3939.4	1265.7	4013.4	1309.2	4088.4	1
2	.0333	1183.0	3867.5	1224.3	3940.6	1266.4	4014.6	1309.9	4089.7	2
3	.0500	1183.7	3868.5	1225.0	3941.8	1267.2	4015.9	1310.6	4091.0	3
4	.0667	1184.4	3869.7	1225.7	3943.0	1267.9	4017.1	1311.3	4092.2	4
5	.0833	1185.1	3870.9	1226.4	3944.2	1268.6	4018.4	1312.1	4093.5	5
6	.1000	1185.7	3872.2	1227.1	3945.5	1269.3	4019.6	1312.8	4094.7	6
7	.1167	1186.4	3873.4	1227.8	3946.7	1270.1	4020.8	1313.5	4096.0	7
8	.1333	1187.1	3874.6	1228.5	3947.9	1270.8	4022.1	1314.2	4097.2	8
9	.1500	1187.8	3875.8	1229.2	3949.2	1271.5	4023.4	1315.0	4098.5	9
10	.1667	1188.5	3877.0	1229.9	3950.4	1272.2	4024.6	1315.7	4099.8	10
11	.1833	1189.2	3878.2	1230.6	3951.6	1272.9	4025.8	1316.5	4101.1	11
12	.2000	1189.8	3879.5	1231.3	3952.9	1273.6	4027.1	1317.2	4102.3	12
13	.2167	1190.5	3880.7	1232.0	3954.1	1274.4	4028.4	1317.9	4103.6	13
14	.2333	1191.2	3881.9	1232.7	3955.3	1275.1	4029.6	1318.6	4104.8	14
15	.2500	1191.9	3883.1	1233.4	3956.6	1275.8	4030.8	1319.4	4106.1	15
16	.2667	1192.6	3884.3	1234.1	3957.8	1276.5	4032.1	1320.1	4107.3	16
17	.2833	1193.3	3885.6	1234.8	3959.0	1277.3	4033.4	1320.8	4108.6	17
18	.3000	1193.9	3886.8	1235.5	3960.2	1278.0	4034.6	1321.5	4109.8	18
19	.3167	1194.6	3888.0	1236.2	3961.5	1278.7	4035.9	1322.3	4111.1	19
20	.3333	1195.3	3889.2	1236.9	3962.7	1279.4	4037.1	1323.0	4112.4	20
21	.3500	1196.0	3890.4	1237.6	3964.0	1280.1	4038.4	1323.7	4113.7	21
22	.3667	1196.7	3891.6	1238.3	3965.2	1280.8	4039.6	1324.4	4114.9	22
23	.3833	1197.4	3892.9	1239.0	3966.4	1281.6	4040.9	1325.2	4116.1	23
24	.4000	1198.0	3894.1	1239.7	3967.6	1282.3	4042.1	1325.9	4117.4	24
25	.4167	1198.7	3895.3	1240.4	3968.9	1283.0	4043.4	1326.7	4118.7	25
26	.4333	1199.4	3896.5	1241.1	3970.1	1283.7	4044.6	1327.4	4119.9	26
27	.4500	1200.1	3897.7	1241.8	3971.3	1284.5	4045.9	1328.2	4121.2	27
28	.4667	1200.8	3898.9	1242.5	3972.5	1285.2	4047.1	1328.9	4122.4	28
29	.4833	1201.5	3900.2	1243.2	3973.8	1285.9	4048.4	1329.7	4123.7	29
30	.5000	1202.1	3901.4	1243.9	3975.0	1286.6	4049.6	1330.4	4125.0	30
31	.5167	1202.8	3902.6	1244.6	3976.3	1287.3	4050.9	1331.1	4126.3	31
32	.5333	1203.5	3903.8	1245.3	3977.5	1288.0	4052.2	1331.8	4127.5	32
33	.5500	1204.2	3905.0	1246.0	3978.8	1288.8	4053.4	1332.6	4128.7	33
34	.5667	1204.9	3906.3	1246.7	3980.0	1289.5	4054.6	1333.3	4130.0	34
35	.5833	1205.6	3907.5	1247.4	3981.2	1290.2	4055.9	1334.1	4131.5	35
36	.6000	1206.2	3908.7	1248.1	3982.4	1290.9	4057.1	1334.8	4132.6	36
37	.6167	1206.9	3909.9	1248.8	3983.7	1291.7	4058.4	1335.6	4133.9	37
38	.6333	1207.6	3911.2	1249.5	3984.9	1292.4	4059.6	1336.3	4135.1	38
39	.6500	1208.3	3912.4	1250.2	3986.2	1293.1	4060.9	1337.1	4136.4	39
40	.6667	1209.0	3913.6	1250.9	3987.4	1293.8	4062.1	1337.8	4137.7	40
41	.6833	1209.7	3914.9	1251.6	3988.7	1294.6	4063.4	1338.5	4139.0	41
42	.7000	1210.4	3916.1	1252.3	3989.9	1295.3	4064.6	1339.2	4140.2	42
43	.7167	1211.0	3917.3	1253.0	3991.1	1296.0	4065.9	1340.0	4141.5	43
44	.7333	1211.7	3918.5	1253.7	3992.3	1296.7	4067.1	1340.7	4142.7	44
45	.7500	1212.4	3919.8	1254.4	3993.6	1297.5	4068.4	1341.5	4144.0	45
46	.7667	1213.1	3921.0	1255.1	3994.8	1298.2	4069.6	1342.2	4145.3	46
47	.7833	1213.8	3922.2	1255.8	3996.0	1298.9	4070.9	1343.0	4146.6	47
48	.8000	1214.5	3923.4	1256.5	3997.3	1299.6	4072.1	1343.7	4147.8	48
49	.8167	1215.2	3924.7	1257.2	3998.6	1300.4	4073.4	1344.5	4149.1	49
50	.8333	1215.9	3925.9	1257.9	3999.8	1301.1	4074.6	1345.2	4150.4	50
51	.8500	1216.6	3927.1	1258.6	4001.0	1301.9	4075.9	1346.0	4151.7	51
52	.8667	1217.3	3928.3	1259.3	4002.2	1302.6	4077.1	1346.7	4153.0	52
53	.8833	1218.0	3929.6	1260.0	4003.4	1303.3	4078.4	1347.5	4154.2	53
54	.9000	1218.7	3930.8	1260.7	4004.7	1304.0	4079.6	1348.2	4155.4	54
55	.9167	1219.4	3932.0	1261.4	4006.0	1304.8	4080.9	1349.0	4156.7	55
56	.9333	1220.1	3933.2	1262.1	4007.2	1305.5	4082.1	1349.7	4158.0	56
57	.9500	1220.8	3934.4	1262.8	4008.5	1306.2	4083.4	1350.5	4159.3	57
58	.9667	1221.5	3935.7	1263.5	4009.7	1306.9	4084.6	1351.2	[illegible]	58
59	.9833	1222.2	3936.9	1264.3	4011.0	1307.7	4085.9	1352.0	[illegible]	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	72° Ext.	72° Tan.	73° Ext.	73° Tan.	74° Ext.	74° Tan.	75° Ext.	75° Tan.	Minutes
0	.0000	1352.7	4163.1	1398.2	4240.0	1444.7	4317.8	1492.5	4396.7	0
1	.0167	1353.5	4164.4	1399.0	4241.3	1445.5	4319.2	1493.3	4398.1	1
2	.0333	1354.2	4165.6	1399.6	4242.6	1446.2	4320.5	1494.1	4399.4	2
3	.0500	1355.0	4166.9	1400.4	4243.9	1447.0	4321.8	1494.9	4400.8	3
4	.0667	1355.7	4168.2	1401.2	4245.1	1447.8	4323.1	1495.7	4402.1	4
5	.0833	1356.5	4169.5	1402.0	4246.4	1448.6	4324.4	1496.5	4403.4	5
6	.1000	1357.2	4170.7	1402.7	4247.7	1449.4	4325.7	1497.3	4404.7	6
7	.1167	1358.0	4172.0	1403.5	4249.0	1450.2	4327.0	1498.2	4406.1	7
8	.1333	1358.7	4173.3	1404.2	4250.3	1451.0	4328.3	1499.0	4407.4	8
9	.1500	1359.5	4174.5	1405.0	4251.6	1451.8	4329.6	1499.8	4408.7	9
10	.1667	1360.2	4175.8	1405.8	4252.9	1452.6	4330.9	1500.6	4410.0	10
11	.1833	1361.0	4177.1	1406.6	4254.2	1453.4	4332.3	1501.4	4411.3	11
12	.2000	1361.7	4178.4	1407.3	4255.5	1454.2	4333.6	1502.2	4412.7	12
13	.2167	1362.5	4179.7	1408.1	4256.8	1454.9	4334.9	1503.0	4414.0	13
14	.2333	1363.2	4181.0	1408.8	4258.1	1455.7	4336.2	1503.8	4415.3	14
15	.2500	1364.0	4182.3	1409.6	4259.4	1456.5	4337.5	1504.6	4416.6	15
16	.2667	1364.7	4183.5	1410.4	4260.7	1457.3	4338.8	1505.4	4418.0	16
17	.2833	1365.5	4184.8	1411.2	4262.0	1458.1	4340.1	1506.2	4419.3	17
18	.3000	1366.2	4186.1	1411.9	4263.2	1458.9	4341.4	1507.0	4420.7	18
19	.3167	1367.0	4187.4	1412.7	4264.5	1459.7	4342.7	1507.9	4422.0	19
20	.3333	1367.7	4188.6	1413.5	4265.8	1460.5	4344.0	1508.7	4423.3	20
21	.3500	1368.5	4189.9	1414.3	4267.1	1461.3	4345.4	1509.5	4424.6	21
22	.3667	1369.2	4191.2	1415.1	4268.4	1462.0	4346.7	1510.3	4426.0	22
23	.3833	1370.0	4192.5	1415.9	4269.7	1462.8	4348.0	1511.2	4427.3	23
24	.4000	1370.7	4193.7	1416.6	4271.0	1463.6	4349.3	1512.0	4428.6	24
25	.4167	1371.5	4195.0	1417.4	4272.3	1464.4	4350.6	1512.8	4430.0	25
26	.4333	1372.2	4196.3	1418.2	4273.6	1465.2	4351.9	1513.6	4431.3	26
27	.4500	1373.0	4197.6	1419.0	4274.9	1466.0	4353.2	1514.5	4432.7	27
28	.4667	1373.7	4198.8	1419.7	4276.2	1466.8	4354.5	1515.3	4434.0	28
29	.4833	1374.5	4200.1	1420.5	4277.5	1467.6	4355.8	1516.1	4435.3	29
30	.5000	1375.2	4201.4	1421.3	4278.8	1468.4	4357.1	1516.9	4436.6	30
31	.5167	1376.0	4202.7	1422.1	4280.1	1469.2	4358.5	1517.7	4438.0	31
32	.5333	1376.7	4204.0	1422.9	4281.4	1469.9	4359.8	1518.5	4439.3	32
33	.5500	1377.5	4205.3	1423.7	4282.7	1470.7	4361.1	1519.4	4440.7	33
34	.5667	1378.2	4206.5	1424.4	4284.0	1471.5	4362.4	1520.2	4442.0	34
35	.5833	1379.0	4207.8	1425.2	4285.3	1472.3	4363.8	1521.0	4443.3	35
36	.6000	1379.7	4209.1	1426.0	4286.6	1473.1	4365.1	1521.8	4444.6	36
37	.6167	1380.5	4210.4	1426.8	4287.9	1473.9	4366.4	1522.7	4446.0	37
38	.6333	1381.2	4211.7	1427.5	4289.2	1474.7	4367.7	1523.5	4447.3	38
39	.6500	1382.0	4213.0	1428.3	4290.5	1475.6	4369.0	1524.3	4448.7	39
40	.6667	1382.8	4214.3	1429.1	4291.8	1476.4	4370.3	1525.1	4450.0	40
41	.6833	1383.6	4215.6	1429.9	4293.1	1477.2	4371.7	1525.9	4451.4	41
42	.7000	1384.3	4216.8	1430.7	4294.4	1478.0	4373.0	1526.7	4452.7	42
43	.7167	1385.1	4218.1	1431.5	4295.7	1478.8	4374.3	1527.6	4454.0	43
44	.7333	1385.8	4219.4	1432.2	4297.0	1479.6	4375.6	1528.4	4455.3	44
45	.7500	1386.6	4220.7	1433.0	4298.3	1480.4	4377.0	1529.2	4456	45
46	.7667	1387.4	4222.0	1433.8	4299.6	1481.2	4378.3	1530.0	4458.0	46
47	.7833	1388.2	4223.3	1434.6	4300.9	1482.0	4379.6	1530.9	4459.4	47
48	.8000	1388.9	4224.5	1435.4	4302.2	1482.8	4380.9	1531.7	4460.7	48
49	.8167	1389.7	4225.8	1436.1	4303.5	1483.6	4382.2	1532.5	4462.1	49
50	.8333	1390.4	4227.1	1436.9	4304.8	1484.4	4383.5	1533.3	4463.4	50
51	.8500	1391.2	4228.4	1437.7	4306.1	1485.2	4384.9	1534.1	4464.7	51
52	.8667	1392.0	4229.7	1438.5	4307.4	1486.0	4386.2	1534.9	4466.0	52
53	.8833	1392.8	4231.0	1439.3	4308.7	1486.9	4387.5	1535.8	4467.4	53
54	.9000	1393.5	4232.3	1440.0	4310.0	1487.7	4388.8	1536.6	4468.7	54
55	.9167	1394.3	4233.6	1440.8	4311.3	1488.5	4390.1	1537.4	4470.1	55
56	.9333	1395.0	4234.8	1441.6	4312.6	1489.3	4391.5	1538.2	4471.4	56
57	.9500	1395.8	4236.1	1442.4	4313.9	1490.1	4392.8	1539.1	4472.7	57
58	.9667	1396.6	4237.4	1443.1	4315.2	1490.9	4394.1	1539.9	4474.1	58
59	.9833	1397.4	4238.7	1443.9	4316.5	1491.7	4395.4	1540.7	4475.4	59

Use 100' Chords up to 8° Curves
Use 50' Chords up to 16° Curves
Use 25' Chords up to 32° Curves
Use 10' Chords above 32° Curves

Minutes	Dec of Degree	76° Ext.	76° Tan.	77° Ext.	77° Tan.	78° Ext.	78° Tan.	79° Ext.	79° Tan.	Minutes
0	0000	1541.5	4476.7	1591.7	4557.8	1643.1	4640.0	1696.0	4723.4	0
1	.0167	1542.4	4478.1	1592.6	4559.2	1644.0	4641.4	1696.9	4724.8	1
2	.0333	1543.2	4479.4	1593.4	4560.5	1644.8	4642.8	1697.7	4726.2	2
3	.0500	1544.1	4480.8	1594.3	4561.9	1645.7	4644.2	1698.6	4727.6	3
4	.0667	1544.9	4482.1	1595.1	4563.3	1646.6	4645.6	1699.5	4729.0	4
5	.0833	1545.7	4483.5	1596.0	4564.7	1647.5	4647.0	1700.4	4730.4	5
6	.1000	1546.5	4484.8	1596.8	4566.0	1648.3	4648.3	1701.3	4731.8	6
7	.1167	1547.4	4486.2	1597.7	4567.4	1649.2	4649.7	1702.2	4733.3	7
8	.1333	1548.2	4487.5	1598.5	4568.7	1650.1	4651.1	1703.1	4734.7	8
9	.1500	1549.1	4488.9	1599.4	4570.1	1651.0	4652.5	1704.0	4736.1	9
10	.1667	1549.9	4490.2	1600.2	4571.5	1651.8	4653.9	1704.9	4737.5	10
11	.1833	1550.7	4491.6	1601.1	4572.9	1652.7	4655.3	1705.8	4738.9	11
12	.2000	1551.5	4492.9	1601.9	4574.2	1653.6	4656.7	1706.6	4740.3	12
13	.2167	1552.4	4494.3	1602.8	4575.6	1654.5	4658.1	1707.5	4741.7	13
14	.2333	1553.2	4495.6	1603.6	4576.9	1655.3	4659.4	1708.4	4743.1	14
15	.2500	1554.1	4497.0	1604.5	4578.3	1656.2	4660.8	1709.3	4744.5	15
16	.2667	1554.9	4498.3	1605.3	4579.7	1657.1	4662.2	1710.2	4745.9	16
17	.2833	1555.7	4499.7	1606.2	4581.1	1658.0	4663.6	1711.1	4747.3	17
18	.3000	1556.5	4501.0	1607.0	4582.4	1658.8	4665.0	1712.0	4748.7	18
19	.3167	1557.4	4502.4	1607.9	4583.8	1659.7	4666.4	1712.9	4750.1	19
20	.3333	1558.2	4503.7	1608.7	4585.1	1660.6	4667.7	1713.8	4751.5	20
21	.3500	1559.1	4505.0	1609.6	4586.5	1661.5	4669.1	1714.7	4752.9	21
22	.3667	1559.9	4506.3	1610.4	4587.9	1662.3	4670.5	1715.6	4754.3	22
23	.3833	1560.7	4507.7	1611.3	4589.3	1663.2	4671.9	1716.5	4755.7	23
24	.4000	1561.5	4509.0	1612.1	4590.6	1664.1	4673.3	1717.4	4757.1	24
25	.4167	1562.4	4510.4	1613.0	4592.0	1665.0	4674.7	1718.3	4758.6	25
26	.4333	1563.2	4511.7	1613.8	4593.3	1665.8	4676.0	1719.2	4760.0	26
27	.4500	1564.1	4513.1	1614.7	4594.7	1666.7	4677.4	1720.1	4761.4	27
28	.4667	1564.9	4514.4	1615.5	4596.0	1667.6	4678.8	1721.0	4762.8	28
29	.4833	1565.7	4515.8	1616.4	4597.4	1668.5	4680.2	1721.9	4764.2	29
30	.5000	1566.5	4517.1	1617.3	4598.8	1669.3	4681.6	1722.8	4765.6	30
31	.5167	1567.4	4518.5	1618.2	4600.2	1670.2	4683.0	1723.7	4767.0	31
32	.5333	1568.2	4519.8	1619.0	4601.5	1671.1	4684.4	1724.6	4768.4	32
33	.5500	1569.1	4521.1	1619.9	4602.9	1672.0	4685.8	1725.5	4769.8	33
34	.5667	1569.9	4522.5	1620.7	4604.3	1672.8	4687.2	1726.4	4771.2	34
35	.5833	1570.7	4523.9	1621.6	4605.7	1673.7	4688.6	1727.3	4772.7	35
36	.6000	1571.5	4525.3	1622.4	4607.0	1674.6	4689.9	1728.2	4774.1	36
37	.6167	1572.4	4526.7	1623.3	4608.4	1675.5	4691.3	1729.1	4775.5	37
38	.6333	1573.2	4528.0	1624.1	4609.8	1676.3	4692.7	1730.0	4776.9	38
39	.6500	1574.0	4529.4	1625.0	4611.2	1677.3	4694.1	1731.0	4778.3	39
40	.6667	1574.8	4530.7	1625.9	4612.5	1678.2	4695.5	1731.9	4779.7	40
41	.6833	1575.6	4532.1	1626.8	4613.9	1679.1	4696.9	1732.8	4781.1	41
42	.7000	1576.4	4533.4	1627.6	4615.3	1679.9	4698.3	1733.7	4782.6	42
43	.7167	1577.3	4534.8	1628.5	4616.7	1680.8	4699.7	1734.6	4784.0	43
44	.7333	1578.1	4536.1	1629.3	4618.0	1681.7	4701.1	1735.5	4785.4	44
45	.7500	1579.0	4537.5	1630.2	4619.4	1682.6	4702.5	1736.4	4786.8	45
46	.7667	1579.8	4538.8	1631.0	4620.8	1683.5	4703.9	1737.3	4788.2	46
47	.7833	1580.7	4540.2	1631.9	4622.2	1684.4	4705.3	1738.2	4789.6	47
48	.8000	1581.5	4541.5	1632.7	4623.5	1685.3	4706.7	1739.1	4791.0	48
49	.8167	1582.4	4542.9	1633.6	4624.9	1686.2	4708.1	1740.0	4792.5	49
50	.8333	1583.2	4544.2	1634.5	4626.3	1687.1	4709.5	1740.9	4793.9	50
51	.8500	1584.1	4545.6	1635.4	4627.7	1688.0	4710.9	1741.8	4795.3	51
52	.8667	1585.0	4547.0	1636.2	4629.0	1688.8	4712.3	1742.7	4796.7	52
53	.8833	1585.8	4548.4	1637.1	4630.4	1689.7	4713.6	1743.6	4798.1	53
54	.9000	1586.6	4549.7	1637.9	4631.8	1690.6	4715.0	1744.5	4799.5	54
55	.9167	1587.5	4551.1	1638.8	4633.2	1691.5	4716.4	1745.4	4801.0	55
56	.9333	1588.4	4552.4	1639.6	4634.5	1692.4	4717.8	1746.3	4802.4	56
57	.9500	1589.2	4553.8	1640.5	4635.9	1693.3	4719.2	1747.2	4803.8	57
58	.9667	1590.0	4555.1	1641.3	4637.3	1694.2	4720.6	1748.1	4805.2	58
59	.9833	1590.9	4556.5	1642.2	4638.7	1695.1	4722.0	[illegible]	[illegible]	59

Use 100' Chords up to 8° Curves — Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves — Use 10' Chords above 32° Curves

Minutes	Dec. of Degree	80° Ext.	80° Tan.	81° Ext.	81° Tan.	82° Ext.	82° Tan.	83° Ext.	83° Tan.	Minutes
0	.0000	1750.0	4808.0	1805.5	4893.9	1862.3	4981.0	1920.6	5069.4	0
1	.0167	1750.9	4809.5	1806.4	4895.4	1863.3	4982.5	1921.6	5070.9	1
2	.0333	1751.8	4810.9	1807.3	4896.8	1864.2	4983.9	1922.6	5072.4	2
3	.0500	1752.8	4812.3	1808.3	4898.3	1865.2	4985.4	1923.6	5073.9	3
4	.0667	1753.7	4813.7	1809.2	4899.7	1866.1	4986.8	1924.6	5075.4	4
5	.0833	1754.6	4815.2	1810.2	4901.2	1867.1	4988.3	1925.6	5076.9	5
6	.1000	1755.5	4816.6	1811.1	4902.6	1868.1	4989.8	1926.5	5078.4	6
7	.1167	1756.5	4818.0	1812.1	4904.0	1869.1	4991.3	1927.5	5079.9	7
8	.1333	1757.4	4819.4	1813.0	4905.4	1870.0	4992.7	1928.5	5081.4	8
9	.1500	1758.3	4820.9	1814.0	4906.9	1871.0	4994.2	1929.5	5082.9	9
10	.1667	1759.2	4822.3	1814.9	4908.3	1871.9	4995.7	1930.5	5084.4	10
11	.1833	1760.1	4823.7	1815.9	4909.8	1872.9	4997.2	1931.5	5085.9	11
12	.2000	1761.0	4825.1	1816.8	4911.2	1873.9	4998.6	1932.4	5087.3	12
13	.2167	1762.0	4826.6	1817.7	4912.7	1874.9	5000.1	1933.4	5088.8	13
14	.2333	1762.9	4828.0	1818.6	4914.1	1875.8	5001.5	1934.4	5090.3	14
15	.2500	1763.8	4829.4	1819.6	4915.5	1876.8	5003.0	1935.4	5091.8	15
16	.2667	1764.7	4830.8	1820.5	4917.0	1877.7	5004.5	1936.4	5093.3	16
17	.2833	1765.7	4832.3	1821.5	4918.5	1878.7	5006.0	1937.4	5094.8	17
18	.3000	1766.6	4833.7	1822.4	4919.9	1879.7	5007.4	1938.4	5096.3	18
19	.3167	1767.5	4835.1	1823.3	4921.4	1880.7	5008.9	1939.4	5097.8	19
20	.3333	1768.4	4836.5	1824.2	4922.8	1881.6	5010.3	1940.4	5099.3	20
21	.3500	1769.3	4838.0	1825.2	4924.3	1882.6	5011.8	1941.4	5100.8	21
22	.3667	1770.2	4839.4	1826.1	4925.7	1883.5	5013.3	1942.4	5102.3	22
23	.3833	1771.2	4840.8	1827.1	4927.2	1884.5	5014.8	1943.4	5103.8	23
24	.4000	1772.1	4842.2	1828.0	4928.6	1885.5	5016.2	1944.4	5105.2	24
25	.4167	1773.0	4843.7	1829.0	4930.1	1886.5	5017.7	1945.4	5106.7	25
26	.4333	1773.9	4845.1	1829.9	4931.5	1887.4	5019.2	1946.4	5108.2	26
27	.4500	1774.9	4846.5	1830.9	4933.0	1888.4	5020.7	1947.4	5109.7	27
28	.4667	1775.8	4847.9	1831.8	4934.4	1889.3	5022.1	1948.4	5111.2	28
29	.4833	1776.7	4849.4	1832.8	4935.8	1890.3	5023.6	1949.4	5112.7	29
30	.5000	1777.6	4850.8	1833.7	4937.3	1891.3	5025.0	1950.4	5114.2	30
31	.5167	1778.5	4852.3	1834.7	4938.7	1892.3	5026.5	1951.4	5115.7	31
32	.5333	1779.4	4853.7	1835.6	4940.2	1893.2	5028.0	1952.4	5117.2	32
33	.5500	1780.4	4855.1	1836.6	4941.7	1894.2	5029.5	1953.4	5118.7	33
34	.5667	1781.3	4856.5	1837.5	4943.1	1895.1	5031.0	1954.4	5120.2	34
35	.5833	1782.2	4858.0	1838.5	4944.6	1896.1	5032.5	1955.4	5121.7	35
36	.6000	1783.1	4859.4	1839.4	4946.0	1897.1	5033.9	1956.4	5123.2	36
37	.6167	1784.1	4860.9	1840.4	4947.5	1898.1	5035.4	1957.4	5124.7	37
38	.6333	1785.0	4862.3	1841.3	4948.9	1899.0	5036.9	1958.4	5126.2	38
39	.6500	1785.9	4863.7	1842.3	4950.4	1900.0	5038.4	1959.4	5127.7	39
40	.6667	1786.8	4865.1	1843.2	4951.8	1901.0	5039.8	1960.4	5129.2	40
41	.6833	1787.7	4866.6	1844.2	4953.3	1902.0	5041.3	1961.4	5130.7	41
42	.7000	1788.6	4868.0	1845.1	4954.7	1902.9	5042.8	1962.4	5132.2	42
43	.7167	1789.6	4869.5	1846.1	4956.2	1903.9	5044.3	1963.4	5133.7	43
44	.7333	1790.5	4870.9	1847.0	4957.6	1904.9	5045.8	1964.4	5135.2	44
45	.7500	1791.5	4872.4	1848.0	4959.1	1905.9	5047.3	1965.4	5136.7	45
46	.7667	1792.4	4873.8	1848.9	4960.6	1906.9	5048.7	1966.4	5138.2	46
47	.7833	1793.4	4875.2	1849.9	4962.1	1907.9	5050.2	1967.4	5139.7	47
48	.8000	1794.3	4876.6	1850.8	4963.5	1908.8	5051.7	1968.4	5141.2	48
49	.8167	1795.3	4878.1	1851.8	4965.0	1909.8	5053.2	1969.4	5142.8	49
50	.8333	1796.2	4879.5	1852.7	4966.4	1910.8	5054.6	1970.4	5144.3	50
51	.8500	1797.1	4880.9	1853.7	4967.9	1911.8	5056.1	1971.4	5145.8	51
52	.8667	1798.0	4882.4	1854.6	4969.3	1912.8	5057.6	1972.4	5147.3	52
53	.8833	1799.0	4883.9	1855.6	4970.8	1913.8	5059.1	1973.4	5148.8	53
54	.9000	1799.9	4885.3	1856.5	4972.2	1914.7	5060.6	1974.4	5150.3	54
55	.9167	1800.9	4886.7	1857.5	4973.7	1915.7	5062.1	1975.4	5151.8	[illegible]
56	.9333	1801.8	4888.1	1858.4	4975.1	1916.7	5063.5	1976.4	5153.3	[illegible]
57	.9500	1802.8	4889.6	1859.4	4976.6	1917.7	5065.0	1977.4	5154.8	[illegible]
58	.9667	1803.7	4891.0	1860.3	4978.0	1918.7	5066.5	1978.4	5156.3	[illegible]
59	.9833	1804.6	4892.5	1861.3	4979.5	1919.7	5068.0	1979.4	5157	[illegible]

Use 100' Chords up to 8° Curves   Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves   Use 10' Chords above 32° Curves

Minutes	Dec. of Degree	84° Ext.	84° Tan.	85° Ext.	85° Tan.	86° Ext.	86° Tan.	87° Ext.	87° Tan.	Minutes
0	.0000	1980.5	5150.3	2041.8	5250.6	2104.8	5343.3	2169.5	5437.5	0
1	.0167	1981.5	5160.8	2042.9	5252.1	2105.9	5344.9	2170.6	5439.1	1
2	.0333	1982.5	5162.3	2043.9	5253.6	2106.9	5346.4	2171.6	5440.7	2
3	.0500	1983.5	5163.8	2045.0	5255.2	2108.0	5348.0	2172.7	5442.3	3
4	.0667	1984.5	5165.3	2046.0	5256.7	2109.1	5349.5	2173.8	5443.9	4
5	.0833	1985.6	5166.9	2047.0	5258.3	2110.1	5351.1	2174.9	5445.5	5
6	.1000	1986.6	5168.4	2048.0	5259.8	2111.2	5352.7	2176.0	5447.1	6
7	.1167	1987.6	5169.9	2049.1	5261.4	2112.3	5354.3	2177.1	5448.7	7
8	.1333	1988.6	5171.4	2050.1	5263.0	2113.4	5355.8	2178.2	5450.3	8
9	.1500	1989.6	5172.9	2051.2	5264.5	2114.5	5357.4	2179.3	5451.9	9
10	.1667	1990.6	5174.4	2052.2	5266.0	2115.5	5358.9	2180.4	5453.4	10
11	.1833	1991.7	5175.9	2053.2	5267.5	2116.6	5360.5	2181.5	5455.0	11
12	.2000	1992.7	5177.5	2054.2	5269.0	2117.6	5362.0	2182.5	5456.6	12
13	.2167	1993.7	5179.0	2055.3	5270.6	2118.7	5363.6	2183.6	5458.2	13
14	.2333	1994.7	5180.5	2056.3	5272.1	2119.8	5365.2	2184.7	5459.8	14
15	.2500	1995.7	5182.0	2057.4	5273.7	2120.9	5366.8	2185.8	5461.4	15
16	.2667	1996.7	5183.5	2058.4	5275.2	2121.9	5368.3	2186.9	5463.0	16
17	.2833	1997.8	5185.0	2059.5	5276.8	2123.0	5369.9	2188.0	5464.6	17
18	.3000	1998.8	5186.6	2060.5	5278.3	2124.1	5371.4	2189.1	5466.2	18
19	.3167	1999.8	5188.0	2061.6	5279.9	2125.2	5373.0	2190.2	5467.8	19
20	.3333	2000.8	5189.6	2062.6	5281.4	2126.2	5374.6	2191.3	5469.4	20
21	.3500	2001.8	5191.0	2063.7	5282.9	2127.3	5376.2	2192.4	5471.0	21
22	.3667	2002.8	5192.6	2064.7	5284.4	2128.3	5377.7	2193.5	5472.5	22
23	.3833	2003.9	5194.0	2065.8	5286.0	2129.4	5379.3	2194.6	5474.1	23
24	.4000	2004.9	5195.6	2066.8	5287.5	2130.5	5380.8	2195.7	5475.7	24
25	.4167	2005.9	5197.2	2067.9	5289.1	2131.6	5382.4	2196.8	5477.3	25
26	.4333	2006.9	5198.7	2068.9	5290.6	2132.6	5383.9	2197.9	5478.9	26
27	.4500	2007.9	5200.2	2070.0	5292.2	2133.7	5385.5	2199.0	5480.5	27
28	.4667	2008.9	5201.7	2071.0	5293.7	2134.8	5387.1	2200.1	5482.1	28
29	.4833	2010.0	5203.2	2072.1	5295.2	2135.9	5388.7	2201.2	5483.7	29
30	.5000	2011.0	5204.7	2073.1	5296.7	2136.9	5390.3	2202.3	5485.3	30
31	.5167	2012.0	5206.3	2074.2	5298.3	2138.0	5391.8	2203.4	5486.9	31
32	.5333	2013.0	5207.8	2075.2	5299.8	2139.0	5393.4	2204.5	5488.5	32
33	.5500	2014.0	5209.3	2076.3	5301.4	2140.1	5395.0	2205.6	5490.1	33
34	.5667	2015.0	5210.8	2077.3	5302.9	2141.2	5396.5	2206.8	5491.7	34
35	.5833	2016.0	5212.4	2078.4	5304.5	2142.3	5398.1	2207.9	5493.3	35
36	.6000	2017.0	5213.9	2079.4	5306.1	2143.3	5399.7	2209.0	5494.9	36
37	.6167	2018.0	5215.4	2080.5	5307.7	2144.4	5401.3	2210.1	5496.5	37
38	.6333	2019.1	5216.9	2081.5	5309.2	2145.5	5402.8	2211.2	5498.1	38
39	.6500	2020.1	5218.4	2082.6	5310.8	2146.6	5404.4	2212.3	5499.7	39
40	.6667	2021.2	5220.0	2083.7	5312.3	2147.7	5406.0	2213.4	5501.3	40
41	.6833	2022.2	5221.6	2084.8	5313.9	2148.8	5407.6	2214.5	5502.9	41
42	.7000	2023.2	5223.1	2085.8	5315.4	2149.8	5409.1	2215.6	5504.5	42
43	.7167	2024.3	5224.6	2086.9	5317.0	2150.9	5410.7	2216.7	5506.1	43
44	.7333	2025.3	5226.1	2087.9	5318.5	2152.0	5412.3	2217.8	5507.7	44
45	.7500	2026.4	5227.7	2089.0	5320.1	2153.1	5413.9	2218.9	5509.3	45
46	.7667	2027.4	5229.2	2090.0	5321.6	2154.2	5415.4	2220.0	5510.9	46
47	.7833	2028.4	5230.7	2091.1	5323.2	2155.3	5417.0	2221.1	5512.5	47
48	.8000	2029.4	5232.2	2092.1	5324.7	2156.4	5418.6	2222.3	5514.1	48
49	.8167	2030.5	5233.8	2093.2	5326.3	2157.5	5420.2	2223.4	5515.7	49
50	.8333	2031.5	5235.3	2094.2	5327.8	2158.6	5421.8	2224.5	5517.3	50
51	.8500	2032.6	5236.8	2095.3	5329.4	2159.7	5423.4	2225.6	5518.9	51
52	.8667	2033.6	5238.3	2096.3	5330.9	2160.7	5424.9	2226.7	5520.5	52
53	.8833	2034.6	5239.9	2097.4	5332.5	2161.8	5426.5	2227.9	5522.1	53
54	.9000	2035.6	5241.4	2098.4	5334.0	2162.9	5428.1	2228.9	5523.7	54
55	.9167	2036.7	5243.0	2099.5	5335.6	2164.0	5429.7	[illegible]	5525.3	55
56	.9333	2037.7	5244.5	2100.6	5337.1	2165.1	5431.2	[illegible]	[illegible]	[illegible]
57	.9500	2038.7	5246.0	2101.7	5338.7	2166.2	5432.8	[illegible]	[illegible]	[illegible]
58	.9667	2039.8	5247.5	2102.7	5340.2	2167.3	5434.4	[illegible]	[illegible]	[illegible]
59	.9833	2040.8	5249.1	2103.8	5341.8	2168.4	5436.0	[illegible]	[illegible]	[illegible]

Use 100' Chords up to 8° Curves Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves Use 10' Chords above 32° Curves

Minutes	Dec. of Degree	88°		89°		90°		91°		Minutes
		Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	.0000	2235.6	5533.3	2303.6	5630.8	2373.4	5730.0	2445.1	5830.9	0
1	.0167	2236.7	5535.0	2304.7	5632.5	2374.6	5731.7	2446.3	5832.6	1
2	.0333	2237.8	5536.6	2305.6	5634.1	2375.8	5733.3	2447.5	5834.3	2
3	.0500	2238.9	5538.2	2307.2	5635.8	2377.0	5735.0	2448.8	5836.0	3
4	.0667	2240.1	5539.8	2308.1	5637.4	2378.2	5736.7	2450.0	5837.7	4
5	.0833	2241.2	5541.5	2309.4	5639.1	2379.4	5738.4	2451.2	5839.4	5
6	.1000	2242.3	5543.1	2310.5	5640.7	2380.5	5740.0	2452.4	5841.1	6
7	.1167	2243.5	5544.7	2311.6	5642.4	2381.7	5741.7	2453.6	5842.8	7
8	.1333	2244.6	5546.3	2312.8	5644.0	2383.0	5743.4	2454.8	5844.5	8
9	.1500	2245.7	5547.9	2314.0	5645.7	2384.1	5745.1	2456.0	5846.2	9
10	.1667	2246.8	5549.5	2315.1	5647.3	2385.3	5746.7	2457.2	5847.9	10
11	.1833	2248.0	5551.2	2316.3	5649.0	2386.4	5748.4	2458.5	5849.6	11
12	.2000	2249.1	5552.8	2317.4	5650.6	2387.6	5750.0	2459.7	5851.3	12
13	.2167	2250.2	5554.4	2318.6	5652.3	2388.8	5751.7	2460.9	5853.0	13
14	.2333	2251.3	5556.0	2319.7	5653.9	2390.0	5753.4	2462.1	5854.7	14
15	.2500	2252.5	5557.6	2320.9	5655.5	2391.2	5755.1	2463.3	5856.4	15
16	.2667	2253.6	5559.3	2322.0	5657.1	2392.4	5756.7	2464.5	5858.1	16
17	.2833	2254.7	5560.9	2323.2	5658.8	2393.5	5758.4	2465.8	5859.8	17
18	.3000	2255.8	5562.5	2324.3	5660.4	2394.7	5760.1	2467.0	5861.5	18
19	.3167	2257.0	5564.1	2325.6	5662.1	2395.9	5761.8	2468.2	5863.2	19
20	.3333	2258.1	5565.7	2326.7	5663.7	2397.1	5763.4	2469.4	5864.9	20
21	.3500	2259.3	5567.3	2327.9	5665.4	2398.3	5765.1	2470.6	5866.6	21
22	.3667	2260.4	5568.9	2329.0	5667.0	2399.5	5766.8	2471.9	5868.3	22
23	.3833	2261.5	5570.6	2330.1	5668.7	2400.7	5768.5	2473.1	5870.1	23
24	.4000	2262.7	5572.2	2331.3	5670.3	2401.9	5770.1	2474.3	5871.8	24
25	.4167	2263.8	5573.8	2332.5	5672.0	2403.1	5771.8	2475.5	5873.5	25
26	.4333	2264.9	5575.4	2333.7	5673.6	2404.3	5773.5	2476.7	5875.2	26
27	.4500	2266.0	5577.0	2334.8	5675.3	2405.5	5775.1	2478.0	5876.9	27
28	.4667	2267.2	5578.6	2336.0	5676.9	2406.6	5776.9	2479.2	5878.6	28
29	.4833	2268.4	5580.3	2337.1	5678.6	2407.8	5778.6	2480.4	5880.4	29
30	.5000	2269.5	5581.9	2338.3	5680.2	2409.0	5780.2	2481.6	5882.0	30
31	.5167	2270.6	5583.5	2339.5	5681.9	2410.2	5781.9	2482.9	5883.7	31
32	.5333	2271.7	5585.1	2340.7	5683.5	2411.4	5783.6	2484.1	5885.4	32
33	.5500	2272.8	5586.8	2341.9	5685.2	2412.6	5785.3	2485.3	5887.2	33
34	.5667	2273.9	5588.4	2343.0	5686.8	2413.8	5787.0	2486.5	5888.9	34
35	.5833	2275.1	5590.1	2344.1	5688.5	2415.0	5788.7	2487.8	5890.6	35
36	.6000	2276.2	5591.7	2345.3	5690.2	2416.2	5790.3	2489.0	5892.3	36
37	.6167	2277.3	5593.3	2346.5	5691.9	2417.4	5792.0	2490.3	5894.0	37
38	.6333	2278.5	5594.9	2347.7	5693.5	2418.6	5793.7	2491.5	5895.7	38
39	.6500	2279.7	5596.6	2348.9	5695.2	2419.8	5795.4	2492.7	5897.5	39
40	.6667	2280.8	5598.2	2350.0	5696.8	2421.0	5797.1	2493.9	5899.2	40
41	.6833	2281.9	5599.8	2351.2	5698.5	2422.2	5798.8	2495.2	5900.9	41
42	.7000	2283.0	5601.4	2352.3	5700.1	2423.4	5800.4	2496.4	5902.6	42
43	.7167	2284.2	5603.1	2353.5	5701.8	2424.6	5802.1	2497.7	5904.3	43
44	.7333	2285.3	5604.7	2354.7	5703.4	2425.8	5803.8	2498.9	5906.0	44
45	.7500	2286.5	5606.4	2355.8	5705.1	2427.0	5805.5	2500.1	5907.7	45
46	.7667	2287.6	5608.0	2357.0	5706.8	2428.2	5807.2	2501.3	5909.4	46
47	.7833	2288.7	5609.6	2358.1	5708.5	2429.4	5808.9	2502.6	5911.2	47
48	.8000	2289.9	5611.2	2359.3	5710.1	2430.6	5810.6	2503.8	5913.0	48
49	.8167	2291.1	5612.9	2360.5	5711.8	2431.8	5812.3	2505.1	5914.6	49
50	.8333	2292.2	5614.5	2361.7	5713.4	2433.0	5814.0	2506.3	5916.3	50
51	.8500	2293.3	5616.2	2362.9	5715.1	2434.2	5815.7	2507.5	5918.1	51
52	.8667	2294.4	5617.8	2364.0	5716.7	2435.4	5817.3	2508.7	5919.8	52
53	.8833	2295.6	5619.4	2365.1	5718.4	2436.6	5819.0	2510.0	5921.5	53
54	.9000	2296.7	5621.0	2366.3	5720.0	2437.9	5820.7	2511.1	5923.3	54
55	.9167	2297.9	5622.7	2367.5	5721.7	2439.1	5822.4	2512.5	5925.0	
56	.9333	2299.0	5624.3	2368.7	5723.4	2440.3	5824.1	2513.7	5926.7	
57	.9500	2300.1	5625.9	2369.9	5725.1	2441.5	5825.8	2515.0	5928.4	
58	.9667	2301.3	5627.5	2371.0	5726.7	2442.7	5827.5	2516.2	5930.[illegible]	
59	.9833	2302.4	5629.2	2372.2	5728.4	2443.9	5829.2	2517.4	[illegible]	

Use 100' Chords up to 8° Curves — Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves — Use 10' Chords above 32° Curves

Minutes	Dec of Degree	92° Ext	92° Tan	93° Ext	93° Tan	94° Ext	94° Tan	95° Ext.	95° Tan.	Minutes
0	0000	2518.7	5933.6	2594.2	6038.2	2671.8	6144.7	2751.5	6253.2	0
1	0167	2520.0	5935.3	2595.5	6040.0	2673.1	6146.5	2752.9	6255.1	1
2	0333	2521.3	5937.0	2596.8	6041.7	2674.4	6148.3	2754.2	6256.9	2
3	0500	2522.4	5938.8	2598.1	6043.5	2675.7	6150.1	2755.6	6258.7	3
4	0667	2523.6	5940.5	2599.3	6045.2	2677.0	6151.9	2756.9	6260.5	4
5	0833	2524.9	5942.3	2600.6	6047.0	2678.4	6153.7	2758.3	6262.4	5
6	1000	2526.1	5944.0	2601.9	6048.7	2679.7	6155.4	2759.6	6264.2	6
7	1167	2527.4	5945.7	2603.2	6050.5	2681.0	6157.2	2761.0	6266.0	7
8	1333	2528.6	5947.4	2604.4	6052.2	2682.3	6159.0	2762.3	6267.8	8
9	1500	2529.9	5949.2	2605.7	6054.0	2683.6	6160.8	2763.7	6269.7	9
10	1667	2531.1	5950.9	2607.0	6055.8	2684.9	6162.6	2765.0	6271.5	10
11	1833	2532.4	5952.7	2608.3	6057.5	2686.3	6164.4	2766.4	6273.4	11
12	2000	2533.6	5954.4	2609.6	6059.3	2687.6	6166.2	2767.7	6275.2	12
13	2167	2534.9	5956.1	2610.9	6061.1	2688.9	6168.0	2769.1	6277.0	13
14	2333	2536.1	5957.8	2612.1	6062.8	2690.2	6169.8	2770.4	6278.8	14
15	2500	2537.4	5959.6	2613.4	6064.6	2691.5	6171.6	2771.8	6280.7	15
16	2667	2538.6	5961.3	2614.7	6066.4	2692.8	6173.4	2773.1	6282.5	16
17	2833	2539.9	5963.1	2616.0	6068.2	2694.2	6175.2	2774.5	6284.4	17
18	3000	2541.1	5964.8	2617.3	6069.9	2695.5	6177.0	2775.8	6286.2	18
19	3167	2542.4	5966.5	2618.6	6071.7	2696.9	6178.8	2777.2	6288.0	19
20	3333	2543.6	5968.2	2619.8	6073.4	2698.1	6180.6	2778.5	6289.8	20
21	3500	2544.9	5970.0	2621.1	6075.2	2699.5	6182.4	2779.9	6291.7	21
22	3667	2546.1	5971.7	2622.4	6077.0	2700.8	6184.2	2781.2	6293.5	22
23	3833	2547.4	5973.5	2623.7	6078.8	2702.1	6186.0	2782.6	6295.4	23
24	4000	2548.6	5975.2	2625.0	6080.5	2703.4	6187.8	2784.0	6297.2	24
25	4167	2549.9	5977.0	2626.3	6082.3	2704.8	6189.7	2785.4	6299.1	25
26	4333	2551.2	5978.7	2627.6	6084.1	2706.1	6191.5	2786.7	6300.9	26
27	4500	2552.5	5980.5	2628.9	6085.9	2707.4	6193.3	2788.1	6302.7	27
28	4667	2553.7	5982.2	2630.2	6087.6	2708.7	6195.1	2789.4	6304.6	28
29	4833	2555.0	5983.9	2631.5	6089.4	2710.1	6196.9	2790.8	6306.4	29
30	5000	2556.2	5985.6	2632.7	6091.2	2711.4	6198.7	2792.1	6308.2	30
31	5167	2557.5	5987.4	2634.0	6093.0	2712.7	6200.5	2793.5	6310.1	31
32	5333	2558.7	5989.1	2635.3	6094.7	2714.0	6202.3	2794.9	6311.9	32
33	5500	2560.0	5990.9	2636.6	6096.5	2715.4	6204.1	2796.3	6313.8	33
34	5667	2561.2	5992.6	2637.9	6098.3	2716.7	6205.9	2797.6	6315.6	34
35	5833	2562.5	5994.4	2639.2	6100.1	2718.0	6207.7	2799.0	6317.5	35
36	6000	2563.8	5996.1	2640.5	6101.8	2719.3	6209.5	2800.3	6319.3	36
37	6167	2565.1	5997.9	2641.8	6103.6	2720.7	6211.4	2801.7	6321.2	37
38	6333	2566.3	5999.6	2643.1	6105.4	2722.0	6213.2	2803.1	6323.0	38
39	6500	2567.6	6001.3	2644.4	6107.2	2723.4	6215.0	2804.5	6324.9	39
40	6667	2568.9	6003.1	2645.7	6109.0	2724.7	6216.8	2805.8	6326.7	40
41	6833	2570.1	6004.9	2647.0	6110.8	2726.0	6218.6	2807.2	6328.6	41
42	7000	2571.4	6006.6	2648.3	6112.5	2727.3	6220.4	2808.6	6330.4	42
43	7167	2572.6	6008.4	2649.6	6114.3	2728.7	6222.3	2810.0	6332.3	43
44	7333	2573.9	6010.1	2650.9	6116.1	2730.0	6224.1	2811.3	6334.1	44
45	7500	2575.2	6011.9	2652.2	6117.9	2731.4	6225.9	2812.7	6336.0	45
46	7667	2576.4	6013.6	2653.5	6119.7	2732.7	6227.7	2814.1	6337.8	46
47	7833	2577.7	6015.4	2654.8	6121.5	2734.1	6229.5	2815.5	6339.7	47
48	8000	2578.9	6017.1	2656.1	6123.2	2735.4	6231.3	2816.8	6341.5	48
49	8167	2580.2	6018.9	2657.4	6125.0	2736.7	6233.2	2818.2	6343.4	49
50	8333	2581.5	6020.6	2658.7	6126.8	2738.0	6235.0	2819.6	6345.2	50
51	8500	2582.8	6022.4	2660.0	6128.6	2739.4	6236.8	2821.0	6347.1	51
52	8667	2584.0	6024.1	2661.3	6130.4	2740.7	6238.6	2822.3	6349.0	52
53	8833	2585.3	6025.9	2662.6	6132.2	2742.1	6240.5	2823.7	6350.9	53
54	9000	2586.6	6027.6	2663.9	6133.9	2743.4	6242.3	2825.1	6352.7	54
55	.9167	2587.9	6029.4	2665.2	6135.7	2744.8	6244.2	[illegible]	6354.6	55
56	.9333	2589.2	6031.1	2666.6	6137.5	2746.1	6246.0	[illegible]	[illegible]	56
57	.9500	2590.4	6032.9	2667.9	6139.3	2747.5	6247.8	[illegible]	[illegible]	57
58	.9667	2591.7	6034.6	2669.2	6141.1	2748.8	6249.6	[illegible]	[illegible]	58
59	.9833	2593.0	6036.4	2670.5	6142.9	2750.2	6251.4	[illegible]	[illegible]	59

Use 100' Chords up to 8° Curves   Use 25' Chords up to 32° Curves
Use 50' Chords up to 16° Curves   Use 10' Chords above 32° Curves

Dec. of Degree	96° Ext	96° Tan	97° Ext	97° Tan	98° Ext	98° Tan	99° Ext	99° Tan	Minutes
.0000	2833.4	6363.8	2917.5	6476.6	3004.0	6591.6	3092.9	6709.6	0
.0167	2834.8	[illegible]	2918.9	6478.5	3005.5	6593.6	3094.4	6711.6	1
.0333	2836.2	6367.3	2920.3	6480.4	3006.9	6595.5	3095.9	6712.9	2
.0500	2837.5	6369.4	2921.8	6482.3	3008.4	6597.5	3097.4	6714.9	3
.0667	2838.9	6371.3	2923.2	6484.2	3009.8	6599.4	3098.9	6716.9	4
.0833	2840.3	6373.2	2924.6	6486.1	3011.3	6601.3	3100.4	6718.9	5
.1000	2841.7	6375.0	2926.0	6488.0	3012.8	6603.3	3101.9	6720.8	6
.1167	2843.2	6376.9	2927.5	6489.9	3014.3	6605.2	3103.4	6722.8	7
.1333	2844.5	6378.7	2928.9	6491.8	3015.7	6607.2	3104.9	6724.8	8
.1500	2845.9	6380.6	2930.3	6493.7	3017.2	6609.1	3106.4	6726.8	9
.1667	2847.2	6382.5	2931.7	6495.6	3018.6	6611.0	3107.9	6728.8	10
.1833	2848.6	6384.4	2933.2	6497.5	3020.1	6613.0	3109.5	6730.8	11
.2000	2850.0	6386.2	2934.6	6499.4	3021.6	6614.9	3111.0	6732.7	12
.2167	2851.4	6388.1	2936.1	6501.3	3023.1	6616.9	3112.5	6734.7	13
.2333	2852.8	6389.9	2937.5	6503.2	3024.5	6618.8	3114.0	6736.7	14
.2500	2854.2	6391.8	2938.9	6505.2	3026.0	6620.8	3115.5	6738.7	15
.2667	2855.6	6393.7	2940.3	6507.2	3027.5	6622.7	3117.0	6740.7	16
.2833	2857.0	6395.6	2941.8	6509.0	3029.0	6624.7	3118.5	6742.7	17
.3000	2858.4	6397.4	2943.2	6510.9	3030.4	6626.6	3120.0	6744.6	18
.3167	2859.8	6399.3	2944.7	6512.8	3031.9	6628.6	3121.5	6746.6	19
.3333	2861.2	6401.2	2946.1	6514.7	3033.3	6630.5	3123.1	6748.6	20
.3500	2862.6	6403.1	2947.5	6516.6	3034.8	6632.5	3124.6	6750.6	21
.3667	2864.0	6404.9	2948.9	6518.5	3036.3	6634.4	3126.1	6752.6	22
.3833	2865.4	6406.8	2950.4	6520.4	3037.8	6636.4	3127.6	6754.6	23
.4000	2866.7	6408.7	2951.8	6522.3	3039.3	6638.3	3129.1	6756.6	24
.4167	2868.1	6410.6	2953.3	6524.3	3040.8	6640.3	3130.7	6758.6	25
.4333	2869.5	6412.4	2954.7	6526.2	3042.2	6642.2	3132.2	6760.6	26
.4500	2870.9	6414.3	2956.1	6528.1	3043.7	6644.2	3133.7	6762.6	27
.4667	2872.3	6416.2	2957.6	6530.0	3045.2	6646.1	3135.2	6764.6	28
.4833	2873.7	6418.1	2959.0	6531.9	3046.7	6648.1	3136.7	6766.6	29
.5000	2875.1	6419.9	2960.4	6533.8	3048.1	6650.0	3138.3	6768.6	30
.5167	2876.5	6421.8	2961.9	6535.8	3049.6	6652.0	3139.8	6770.6	31
.5333	2877.9	6423.7	2963.3	6537.7	3051.1	6653.9	3141.3	6772.6	32
.5500	2879.3	6425.6	2964.8	6539.6	3052.6	6655.9	3142.9	6774.6	33
.5667	2880.8	6427.5	2966.2	6541.5	3054.1	6657.8	3144.4	6776.6	34
.5833	2882.2	6429.4	2967.7	6543.4	3055.6	6659.8	3145.9	6778.6	35
.6000	2883.6	6431.2	2969.1	6545.3	3057.0	6661.7	3147.4	6780.6	36
.6167	2885.0	6433.1	2970.6	6547.3	3058.5	6663.7	3149.0	6782.6	37
.6333	2886.4	6435.0	2972.0	6549.2	3060.0	6665.7	3150.5	6784.6	38
.6500	2887.8	6436.9	2973.5	6551.1	3061.5	6667.7	3152.0	6786.6	39
.6667	2889.2	6438.8	2974.9	6553.0	3063.0	6669.6	3153.5	6788.6	40
.6833	2890.6	6440.7	2976.4	6555.0	3064.5	6671.6	3155.1	6790.6	41
.7000	2892.0	6442.5	2977.8	6556.9	3066.0	6673.5	3156.6	6792.6	42
.7167	2893.4	6444.4	2979.3	6558.8	3067.5	6675.5	3158.2	6794.6	43
.7333	2894.8	6446.3	2980.7	6560.7	3068.9	6677.4	3159.7	6796.6	44
.7500	2896.3	6448.2	2982.2	6562.7	3070.4	6679.4	3161.2	6798.6	45
.7667	2897.7	6450.1	2983.6	6564.6	3071.9	6681.4	3162.7	6800.6	46
.7833	2899.1	6452.0	2985.1	6566.5	3073.4	6683.4	3164.3	6802.6	47
.8000	2900.5	6453.9	2986.5	6568.4	3074.9	6685.3	3165.8	6804.6	48
.8167	2902.0	6455.8	2988.0	6570.4	3076.4	6687.3	3167.4	6806.6	49
.8333	2903.3	6457.6	2989.4	6572.3	3077.9	6689.2	3168.9	6808.6	50
.8500	2904.7	6459.5	2990.9	6574.2	3079.4	6691.2	3170.5	6810.6	51
.8667	2906.1	6461.4	2992.3	6576.2	3080.9	6693.2	3172.0	6812.6	52
.8833	2907.6	6463.3	2993.8	6578.1	3082.4	6695.2	3173.6	6814.7	53
.9000	2909.0	6465.2	2995.2	6580.0	3083.9	6697.1	3175.1	6816.7	54
.9167	2910.4	6467.1	2996.7	6582.0	3085.4	6699.1	3176.6	6818.7	55
.9333	2911.8	6469.0	2998.1	6583.9	3086.9	6701.1	3178.2	6820.7	56
.9500	2913.3	6470.9	2999.6	6585.8	3088.4	6703.1	3179.7	6822.7	57
.9667	2914.7	6472.8	3001.1	6587.7	3089.9	6705.1	3181.2	6824.7	58
.9833	2916.1	6474.7	3002.6	6589.7	3091.4	6707.1	3182.8	6826.7	59

Use 100′ Chords up to 8° Curves
Use 50′ Chords up to 16° Curves

Use 25′ Chords up to 32° Curves
Use 10′ Chords above 32° Curves

Minutes	Dec. of Degree	100° Ext.	100° Tan.	Minutes
0	.0000	3184.3	6828.8	0
1	.0167	3185.9	6830.8	1
2	.0333	3187.4	6832.8	2
3	.0500	3189.0	6834.8	3
4	.0667	3190.5	6836.8	4
5	.0833	3192.1	6838.9	5
6	1000	3193.6	6840.9	6
7	1167	3195.2	6842.9	7
8	1333	3196.7	6844.9	8
9	1500	3198.3	6847.0	9
10	.1667	3199.8	6849.0	10
11	1833	3201.4	6851.0	11
12	2000	3202.9	6853.0	12
13	2167	3204.5	6855.1	13
14	2333	3206.0	6857.1	14
15	2500	3207.6	6859.1	15
16	2667	3209.1	6861.1	16
17	2833	3210.7	6863.2	17
18	3000	3212.2	6865.2	18
19	3167	3213.8	6867.2	19
20	3333	3215.4	6869.2	20
21	3500	3217.0	6871.3	21
22	3667	3218.5	6873.3	22
23	3833	3220.1	6875.4	23
24	4000	3221.6	6877.4	24
25	4167	3223.2	6879.4	25
26	4333	3224.7	6881.5	26
27	4500	3226.3	6883.5	27
28	4667	3227.9	6885.5	28
29	.4833	3229.5	6887.6	29
30	5000	3231.0	6889.6	30
31	5167	3232.6	6891.7	31
32	5333	3234.1	6893.7	32
33	5500	3235.7	6895.7	33
34	5667	3237.3	6897.8	34
35	5833	3238.9	6899.8	35
36	.6000	3240.4	6901.8	36
37	6167	3242.0	6903.9	37
38	6333	3243.5	6905.9	38
39	6500	3245.1	6908.0	39
40	.6667	3246.7	6910.0	40
41	.6833	3248.3	6912.1	41
42	7000	3249.8	6914.1	42
43	7167	3251.4	6916.2	43
44	7333	3253.0	6918.2	44
45	7500	3254.6	6920.3	45
46	7667	3256.2	6922.3	46
47	7833	3257.8	6924.4	47
48	.8000	3259.3	6926.4	48
49	.8167	3260.9	6928.5	49
50	8333	3262.5	6930.5	50
51	8500	3264.1	6932.6	51
52	8667	3265.7	6934.6	52
53	8833	3267.3	6936.7	53
54	9000	3268.8	6938.7	54
55	9167	3270.4	6940.8	55
56	9333	3272.0	6942.8	56
57	9500	3273.6	6944.0	57
58	.9667	3275.2	6946.9	58
59	.9833	3276.8	6949.0	59

Use 100′ Chords up to 8° Curves Use 25′ Chords up to 32° Curves
Use 50′ Chords up to 16° Curves Use 10′ Chords above 32° Curves

Minutes	101°		102°		103°		104°		105°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	3278.3	6951.0	3375.1	7076.0	3474.6	7203.6	3577 1	7334.1	3682.6	7467 5	0
0	3294.3	6971 7	3391 5	7097 1	3491 5	7225.1	3594.4	7356 1	3700.4	7490.0	10
0	3310 3	6992.4	3407.9	7118.2	3508.4	7246 8	3611 9	7378.2	3718.4	7512.6	20
0	3326.4	7013.2	3424 5	7139 4	3525 5	7268.5	3629.4	7400.4	3736 5	7535.3	30
0	3342.5	7034.0	3441 1	7160.7	3542.6	7290.3	3647 1	7422 7	3754.6	7558.1	40
0	3358.8	7055.0	3457.8	7182.1	3559.8	7312 1	3664.8	7445.0	3772.9	7581.0	50
0	3375.1	7076.0	3474.6	7203.6	3577 1	7334 1	3682.6	7467 5	3791.2	7604.0	60

Minutes	106°		107°		108°		109°		110°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	3791 2	7604.0	3903.1	7743.7	4018.5	7886 7	4137 4	8033.2	4260.0	8183.3	0
0	3809 6	7627.0	3922.1	7767 5	4038.0	7910.8	4157 5	8057 9	4280.8	8208.7	10
0	3828 1	7650.2	3941.2	7791.0	4057.7	7935 1	4177.8	8082.8	4301 7	8234 2	20
0	3846.7	7673.4	3960.4	7814.7	4077 5	7959.5	4198 2	8107.8	4322 7	8259.8	30
0	3865.4	7696.7	3979.6	7838.6	4097.3	7983 9	4218.7	8132.8	4343.8	8285 5	40
0	3884.2	7720.1	3999.0	7862.6	4117.3	8008 5	4239.3	8158.0	4365 1	8311 3	50
0	3903 1	7743 7	4018.5	7886 7	4137.4	8033 2	4260.0	8183.3	4386.4	8337 2	60

Minutes	111°		112°		113°		114°		115°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	4386.4	8337 2	4516 9	8495 1	4651 6	8657 1	4790.7	8823.4	4934.4	8994.5	0
0	4407.9	8363 2	4539.1	8521.8	4674.5	8684.5	4814 4	8851.6	4958.9	9023 2	10
0	4429.5	8389.4	4561 3	8548.6	4697 5	8712.0	4838.1	8879.9	4983.4	9052 3	20
0	4451 2	8415 6	4583 7	8575.6	4720 6	8739.7	4862.0	8908 3	5008 1	9081.5	30
0	4473.0	8442.0	4606 2	8602 6	4743.9	8767.5	4885 0	8936.8	5032.9	9110.8	40
0	4494.9	8468.5	4628.9	8629.8	4767 2	8795.4	4910.2	8965 5	5057 9	9140.3	50
0	4516.9	8495.1	4651.6	8657 1	4790.7	8823.4	4934.4	8994 3	5083.0	9169.9	60

Minutes	116°		117°		118°		119°		120°		Minutes
	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	Ext.	Tan.	
0	5083.0	9169.9	5236 6	9350.5	5395.4	9536.3	5559.7	9727 6	5730.0	9,924.6	0
10	5108.2	9199 7	5262.6	9381 1	5422 4	9567.8	5587.7	9760.0	5758.9	9,958.1	10
20	5133.6	9229.6	5288.9	9411 9	5449.5	9599.5	5615 8	9792.6	5788.0	9,990.6	20
30	5159.1	9259.6	5315 3	9442.8	5476 8	9631 3	5644 1	9825 4	5817.3	10,025 6	30
40	5184.8	9289.8	5341.8	9473.8	5504 3	9663 2	5672 6	9858.3	5846.8	10,059 7	40
50	5210.6	9320.1	5368.5	9505 0	5532.0	9695 3	5701 2	9891.4	5876.4	10,093 7	50
60	5236.6	9350.5	5395.4	9536.3	5559.7	9727.6	5730.0	9924.6	5906 1	10 127.7	60

$$L = 100 \times \frac{\Delta}{D} = \frac{\text{central angle}}{\text{Degree of curvature}} \times 100.$$

For the convenience of the field engineer column 1, Table 30, gives the central angle (Δ) in degrees and minutes (as read by the transit); column 2 gives the same angle expressed in degrees and decimals for figuring curve lengths.

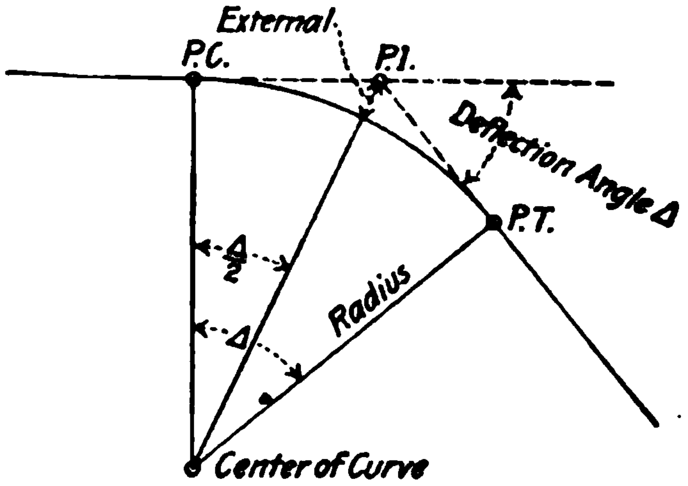


FIG. 52

Tangent length and externals.
Sketch No. 52 shows a general curve problem. The deflection angle between the tangents at the point of intersection (P.I.) = the central angle of the curve that will fit these tangents; it is referred to as Δ.

The tangent distances equal the distance from the *P. C.* (beginning of curve) to the *P. I.* or *P. I.* to *P. T.* (end of curve) and is expressed by the formula

$$\text{T} = \text{Radius} \times \text{tangent of } \frac{\Delta}{2} \qquad (4)$$

Therefore, for a given central angle Δ, the tangent length is directly proportional to the radius. If the tangent lengths of a $1°$ curve for different Δ's are tabulated, the tangent length for any desired degree of curve equals tangent length for $1°$ curve for the specified Δ divided by the degree of the desired curve expressed in degrees and decimals of a degree.

Expressed as a formula this reads:

$$\text{Tangent for desired curve} = \frac{\text{Tangent } 1° \text{ curve for specified } \Delta}{D} \qquad (5)$$

and reversing the formula we can determine the desired degree of curve for a specified tangent length by the formula

$$D = \frac{\text{Tangent } 1° \text{ curve for specified } \Delta}{\text{Specified tangent length desired.}} \qquad (6)$$

The external is the distance from the *P. I.* to the curve arc on the line between the *P. I.* and the center of the curve. It is determined by the formula:

$$Ext = \frac{\text{Radius}}{\text{Cosine } \frac{\Delta}{2}} - \text{Radius} = \text{Radius}\left(\frac{1}{\text{Cosine } \frac{\Delta}{2}} - 1\right) \qquad (7)$$

and is directly

tional to the radius in the same manner as the tangent . therefore, the external of any desired curve for a specified als the external of a 1° curve for that Δ divided by the of curvature.

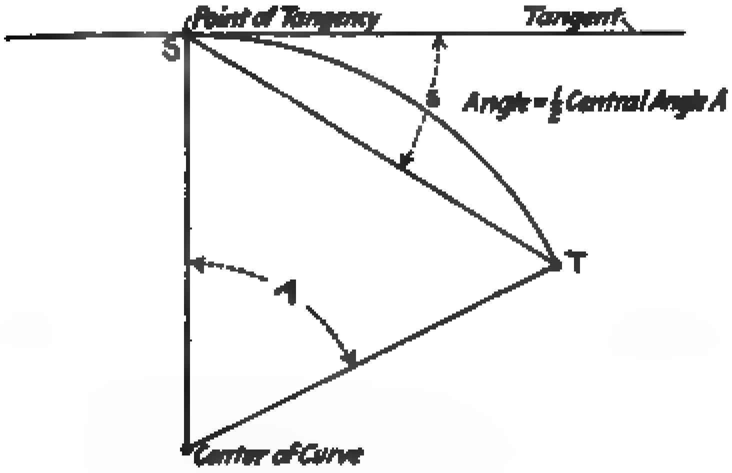


FIG. 53

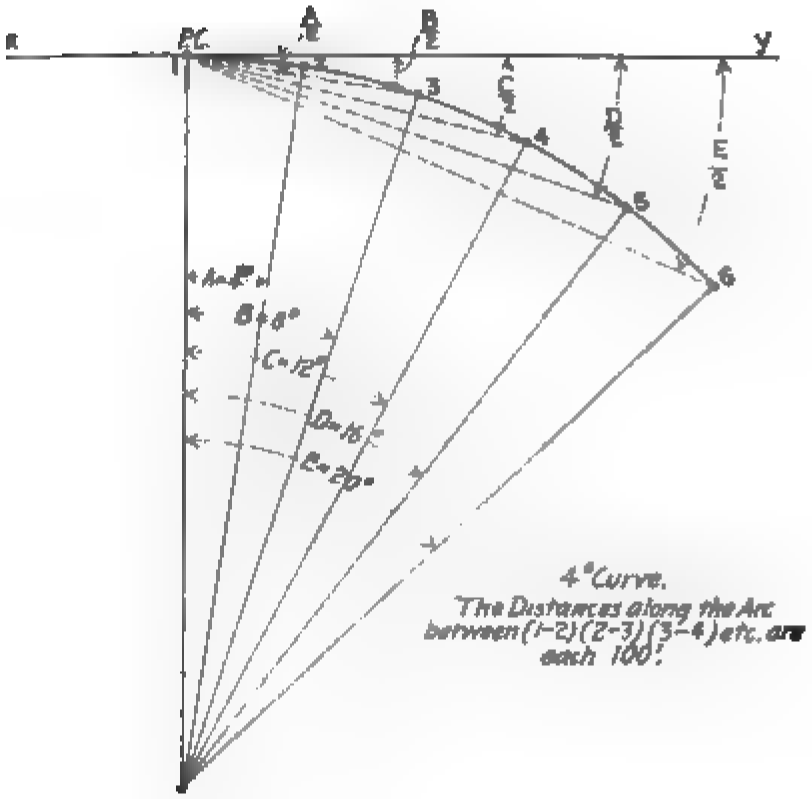


FIG. 54

ressed as a formula this reads:

$$\text{ernal for desired curve} = \frac{\text{Ext. 1° curve for specified } \Delta}{D} \quad (8)$$

and reversing, as for tangents, the desired degree of curvature is obtained that gives a specified external distance, by the formula,

$$D = \frac{\text{Ext. } 1^\circ \text{ curve for specified } \Delta}{\text{Specified Ext. distance desired.}} \qquad (9)$$

Methods of running curves. Curves are run in the field by tangent offsets, middle ordinates or deflection angles. Deflection angles is the simplest method and is almost universally used. It is based on the principle that the angle S between the tangent and arc chord, one end of which is at the point of tangency, is equal to ½ the central angle subtended by that chord. Suppose the angle A is 4° and the arc length ST = 100 feet. This curve would then be a 4° curve. From the previous definitions locate the point T (Fig. 53) by turning the deflection angle $S = 2^\circ$ from the tangent and measuring 100 feet of arc in such a position that the end of the arc would be on the line of the chord ST. It is impossible to conveniently measure the arc distance and for all practical purposes a chord length of 100′ will answer for a 4° curve (see discussion, page 173).

Suppose we wish to locate the points 2, 3, 4, 5, and 6 on the 4° curve from point 1 or the $P. C.$ of a curve (Fig. 54).

Set the transit at the $P. C.$; if we turn a deflection $\frac{A}{2} = 2^\circ$ from the tangent xy the line of sight will pass through the point 2; if we turn $\frac{B}{2} = 4^\circ$ the line of sight will pass through point 3; 6°, point 4, etc.; it only remains to measure to these points to locate them definitely. This can be done in two ways, by measuring the distances 1–2, 1–3, 1–4, 1–5, etc., or by measuring 1–2, 2–3, 3–4, 4–5, etc.

In the first case the difference between the length of arc and the chord length becomes so great that, unless a correction is made, the points are not exactly located; that is, the length of arc between points 1, 2, 3, 4, 5, 6, = 500′ while the chord length 1–6 = 497.5′; also, it takes longer to measure the distances 1–2, 1–3, 1–4, 1–5, 1–6, etc., than it would 1–2, 2–3, 3–4, 4–5, etc.

In the second method we can use chords of 100′ from 1–2, 2–3, etc., with no appreciable error, as the distance measured by chords 1, 2, 3, 4, 5, 6, = 499.94′.

Therefore, the method usually adopted is to turn the deflection angle $\frac{A}{2}$ and measure the chord 1–2, which locates the point 2; then turn the deflection angle $\frac{B}{2}$ and measure the chord distance 2–3, locating point 3, etc.

The fact has been mentioned that the use of the chord distance as equal to the arc introduces an error but that this error is of no importance for a 4° curve: As the degree of curvature increases, *the difference* between an arc length of 100′ and the chord length *becomes greater,* and it is necessary to determine the limit of *curvature that* will allow the use of 100′ chords in locating curve

points. On page 118 the statement is made that center line chaining should be correct to within 0.1′ per 100′ of length, which allows a difference in arc and chord of 0.1′ This occurs when the degree of curvature reaches 9° per 100′. The difference can then be reduced by the simple expedient of using 50′ chords, which reduces the error for this degree of curvature from 0.10′ per 100′ of length using 100′ chords to 0.02′ using 50′ chords; 50′ chords can be used up to 18° curves and beyond that point 25′ chords.

It is better not to use the full limit of allowable error, and a good working rule is 100′ chords up to 8° curves, 50′ chords up to 16° curves, 25′ chords to 32° and beyond that 10′ chords.

For any given curve the deflection angle and central angle are directly proportional to the length of the arc, and if the deflection angle for 100′ arc of 10° curve equals 5° the deflection angle for one foot of arc of 10° curve equals $\frac{5^\circ}{100} = \frac{300'}{100} =$ 3 minutes.

An example of a typical simple curve problem can now be given:

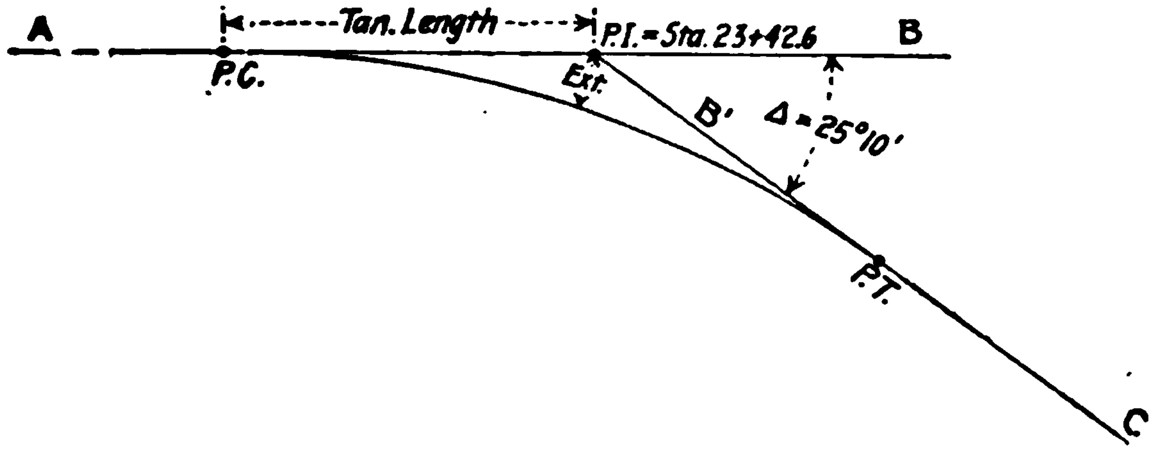


FIG. 55

To determine the degree of curvature desired from a fixed external distance

At station 23 + 42.6 we have a deflection angle of 25° 10′ between tangents *AB* and *B′C;* suppose upon examining the ground it is decided that to fit the old roadbed and give good alignment the curve should be located somewhere between 13.5′ and 14.5′ to the right of the transit point at station 23 + 42.6. Proceed as follows: from table 30 pick out the external for a 1° curve for Δ = 25° 10′, this equals 141.0′.

The problem is to determine the degree of curvature that will give an external of between 13.3′ and 14.5′. Use formula (9).

$$D = \frac{\text{Ext. } 1^\circ \text{ curve for } 25^\circ\ 10'}{13.5'} = \frac{141.0'}{13.5'} = 10.44^\circ \text{ curve.}$$

$$D = \frac{\text{Ext. } 1^\circ \text{ curve for } 25^\circ\ 10'}{14.5'} = \frac{141.0'}{14.5} = 9.72^\circ \text{ curve.}$$

To fit the conditions some curve must be selected between a

10.44° and a 9.72°. A 10° curve would be naturally selected as being the simplest to figure.

To determine the required degree of curvature for a fixed tangent length

Take the same problem as above except there must be a tangent length of between 127′ and 129′. Use formula (6).

$$D = \frac{\text{Tangent } 1° \text{ curve for } 25° \ 10'}{127'} = \frac{1279.1'}{127'} = 10.07° \text{ curve.}$$

$$D = \frac{\text{Tangent } 1° \text{ curve for } 25° \ 10}{129'} = \frac{1279.1'}{129'} = 9.91° \text{ curve.}$$

Table No. 30 gives tangent for 25° 10′ = 1279.1′.

These limiting values would result in the selection of a 10° curve. The degree of the desired curve is usually selected in one of these two ways; ordinarily it is determined by the external distance.

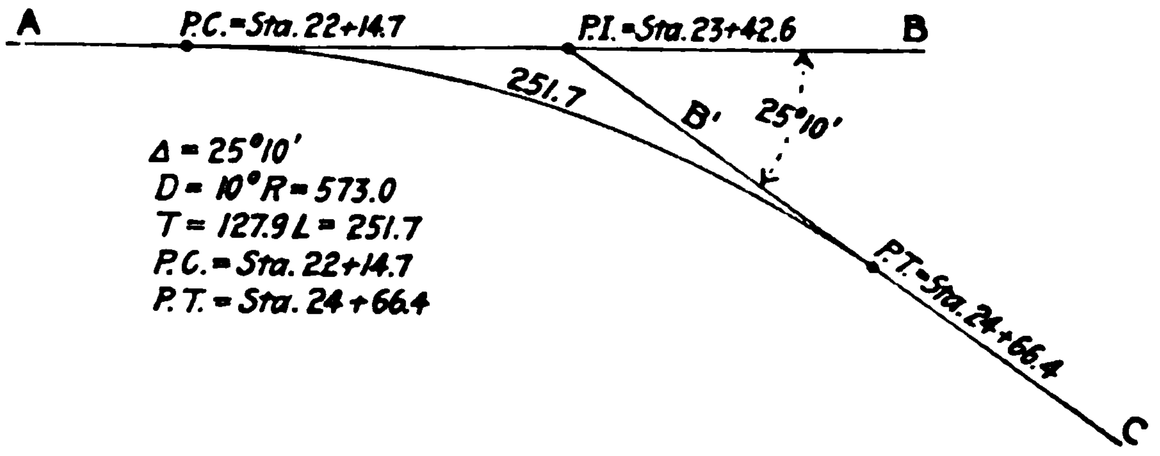


FIG. 56

Simple Curve Problem. Case 1.

To compute the notes for a 10° curve for a deflection angle of 25° 10′ between tangents at station 23 + 42.6.

Central angle = 25° 10′.

Table No. 30 gives the tangent 1° curve for 25° 10′ = 1279.1.

$$\text{Tangent } 10° \text{ curve} = \frac{1279.1}{10} = 127.91$$

The station of the *P.C.* then equals station 23 + 42.6 *P.I.* minus 127.9′ = station 22 + 14.7.

$$\text{The length of curve} = \frac{\Delta}{D} = \frac{25.16667°}{10°} \times 100' = 251.7 \text{ feet.}$$

The station of the *P.T.* (Tangent point, or end of the curve) as measured around the arc is then station (22 + 14.7 *P.C.*) + 251.7′ = station 24 + 66.4.

The rule for running curves requires the use of 50′ chords for a 10° curve. We must, therefore, figure the deflections for the even stations and the 50′ stations as follows:

Station 22 + 50, 23 + 00, 23 + 50, 24 + 00, 24 + 50, and *to check the curve* station 24 + 66.4.

For a 10° curve, Table No. 29.

The deflection for 100′ of arc = 5°
" " " 50′ " " = 2° 30′
" " " 1′ " " = 0° 03′

The distance from the *P.C.* station 22 + 14.7 to station 22 + 50 is 35.3′; the deflection per foot = 0° 03′, for 35.3′ = 35.3 × 0° 03′ = 105.9 minutes = 1° 46′.

The distance *P.C.* to station 23 + 00 equals 85.3′, or 50′ farther than for station 22 + 50; the deflection per 50′ of arc equals 2° 30′; therefore, the deflection for station 23 + 00 equals the deflections for station 22 + 50 (1° 46′) plus 2° 30′, the deflection for 50′ of arc or 4° 16′; in a like manner the deflection for station 23 + 50 is 6° 46′; for 24 + 00, 9° 16′; for 24 + 50, 11° 46′; the distance from station 24 + 50 to the *P.T.* station 24 + 66.4 is 16.4′; the deflection for 16.4′ equals 16.4 × 0° 03′ = 49.2′; the deflection for station 24 + 66.4 is, therefore, (11° 46′ + 49′) = 12° 35′; if the deflection notes have been properly figured this last deflection to the *P.T.* should always be ½ the central angle of the curve; in this case ½ of 25° 10′, which equals 12° 35′, checking the notes.

To run the curve. Set up the transit at the *P.I.*; sight along the tangent (*B.A.*), measure off the distance 127.9 (tangent length) along this line and set the *P. C.* exactly on the line. In a like manner set the *P.T.* on the forward tangent (*B′.C.*) 127.9′ from the *P.I.* Then set up the transit on the *P.C.* and with the vernier at 0° 00′ sight on the *P.I.*, using the lower plate motion. Loosen the upper motion and deflect 1° 46′; measure along this line 35.3′, which locates station 22 + 50 on the curve arc; then loosen the upper motion and set the vernier to read 4° 16′; measure 50′ from the just located station 22 + 50, so that the forward end of the tape is in line with the transit deflection of 4° 16′; this locates station 23 + 00 on the curve arc. In a like manner deflect 6° 46′ and measure forward 50′ from station 23 + 00 to station 23 + 50, etc., until the *P.T.* is reached. If the curve has been correctly run the last deflection of 12° 35′ will strike the previously located *P. T.* and the distance from station 24 + 50 to this *P.T.* will be 16.4′; if the distance checks within 0.2′ it is sufficiently close.

The above problem and method of laying out a curve is the simplest form encountered; in it we assume that the *P.I.*, *P.T.* and all intermediate points on the curve are visible from the *P.C.* and that the *P.I.* is accessible.

In nine cases out of ten this method is applicable to road curves, but where the *P.I.* occurs outside of the road fences it sometimes is located in a stream, pond, building, etc., and cannot be occupied. This is known as the problem of the inaccessible *P.I.* More often it is impossible to see the *P.T.*, or some intermediate point on the curve from the *P.C.*, which necessitates intermediate transit points on the curve. The problem of inaccessible *P.C.s or P.T.s* is so rare it will not be illustrated.

Problem of the Inaccessible P. I. Case 2.

The point H ($P.I.$) cannot be occupied. Locate any two convenient points, s and t on the tangents $A.B.$ and $B'.C.$ and measure the distance st equals, say, 110.5′.

Set the transit at s and measure the angle between the line $A.s.$ produced and st, say, 5° 10′; in a similar manner measure the angle at t between st produced and the forward tangent tC, say, 20° 00′. The total deflection then between the tangent AsB and $B'tC$ or the central angle of the curve to be run is the sum of these two deflections, angles (5° 10′) + (20° 00′) = 25° 10′.

Assuming a 10° curve is desired we must locate the $P.C.$ from the point s and the $P.T.$ from the point t.

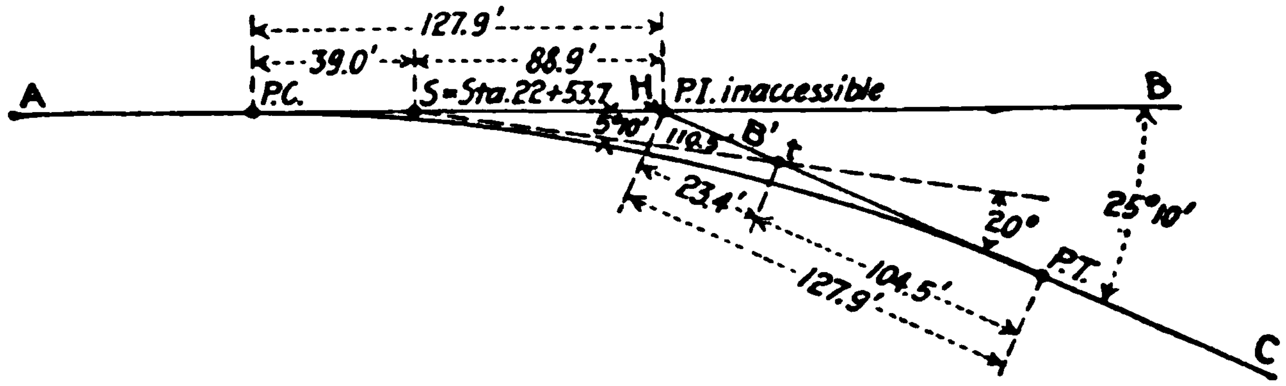


FIG. 57

In the preceding simple curve problem the tangent length of a 10° curve with a central angle of 25° 10′ was figured to be 127.9′; it, therefore, remains to compute the distance sH which subtracted from 127.9′ will give the distance from s along the tangent sA to the $P.C.$, of the curve. In a similar manner compute tH, which subtracted from 127.9′ gives the distance along the forward tangent tC to the $P.T.$ of the curve.

Knowing the station of the point s as measured along the tangent $A.B.$ the station of the $P.C.$ is determined; then figure the deflections in the usual manner and run the curve.

For the values given the computations are as follows:

To determine sH and Ht. Use the law of sines (see Trigonometric formulæ, page 374).

$sH : st :$ sin 20° 00′ : sin 25° 10′

$$sH = \frac{st \sin 20^\circ 00'}{\sin 25^\circ 10'} = \frac{110.5 \times 0.34202}{0.42525} = 88.87'$$

$$Ht = \frac{st \sin 5^\circ 10'}{\sin 25^\circ 10'} = \frac{110.5 \times 0.09005}{0.42525} = 23.4'$$

Therefore, the distance from s to the $P.C.$ is 127.9′ − 88.9′ = 39.0′.

The distance from t to the $P.T.$ is 127.9 − 23.4 = 104.5.

Having these distances the $P.C.$ and $P.T.$ are located. Assume that station of s was measured along the tangent AB and found to be station 22 + 53.7.

The station of the *P.C.* then equals 22 + 14.7
" " " " *P.I.* " " 23 + 42.6
" " " " *P.T.* " " 24 + 66.4, using the length of curve figured in *Case* 1.

The deflections are figured and the curve run as in Case 1, assuming that all the curve points are visible from the *P.C.*

Case 3. *Where the P.T. or intermediate points on the curve are not visible from the P.C.*

(*a*) *Where an intermediate set-up is required. Use the same curve as in Case* 1.

The deflections for the different curve points were figured as follows:

Deflections. Instrument at P.C., foresight on P.I.

P.C. Station	22 + 14.7	Deflection	0° 00′
	22 + 50	"	1° 46
	23 + 00	"	4° 16′
	23 + 50	"	6° 46′
	24 + 00	"	9° 16′
	24 + 50	"	11° 46′
	24 + 66.4	"	12° 35′

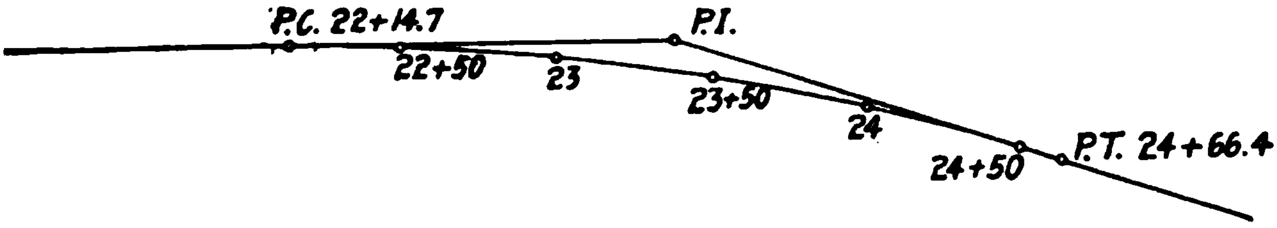


FIG. 58

Set up the instrument at the *P.C.* and locate the points 22 + 50, 23 + 00 and 23 + 50; suppose 24 + 00 is not visible, set up at station 23 + 50, set the vernier at 0° 00′ and back sight on the *P.C.*; transit the telescope and finish the curve, using the same deflections as figured for the instrument set up at the *P.C.*; that is, turn the deflection of 9° 16′ for station 24 + 00, 11° 46′ for 24 + 50, and 12° 35′ for the *P.T.* In general it can be said that whenever the *P.C.* is used as a back-sight from the intermediate set-up, set the vernier at 0° 00′ when sighting on the *P.C.*; transit the telescope and use original notes for the balance of the curve.

(*b*) *Where two or more intermediate set-ups are required.*

For the first set-up, say, at 23 + 50, proceed as above and set station 24 + 00; suppose 24 + 50 is not visible from station 23 + 50; set up at station 24 + 00 and with the vernier reading 6° 46′ back sight on station 23 + 50; transit the telescope, set the vernier to read 11° 46′ for station 24 + 50, and proceed, using the same deflections as originally figured. In general, where the *P.C. is not visible* from the intermediate set-up, set the

vernier to read the deflection figured for the point used as a backsight; transit the telescope and proceed with the curve, using the notes originally figured. That is, if the instrument is set up at station 24 + 00 and 22 + 50 used as a backsight, the vernier is set at 1° 46′, and using the lower motion the wire is set on station 22 + 50; then transiting the telescope the curve is run by setting the vernier at 11° 46′ for station 24 + 50, etc.

If station 23 + 00 is used as a backsight, set the vernier at 4° 16′ when sighting the machine; then transit and proceed as above.

These three cases cover any ordinary road curve problems.

CHAPTER IX

OFFICE PRACTICE

Under office practice we include

1. Mapping the preliminary survey.
2. Designing the improvement and estimating the quantities.
3. Producing a finished set of plans from which the road can be constructed.

1. Mapping the preliminary survey.

The mapping of the preliminary survey serves as a base from which the design of the new work, and the quantities necessary thereto, can be built up. It consists of three views of the road: the plan, showing the topographic features; the profile, showing the longitudinal differences of elevation, and the cross-sections, showing the constantly changing transverse shape.

The scales in general use are as follows:

Plan	Profile	Cross-sections
$1'' = 100'$	$1'' = 100'$ horizontal $1'' = 10'$ vertical	$1'' = 10'$
$1'' = 50'$	$1'' = 50'$ horizontal $1'' = 10'$ vertical	$1'' = 5'$ or $1'' = 4'$
$1'' = 20'$	$1'' = 20'$ horizontal $1'' = 5'$ vertical	$1'' = 5'$ or $1'' = 4'$
$1'' = 10'$	$1'' = 10'$ horizontal $1'' = 10'$ vertical	$1'' = 2'$

The $100'$ scale is too small for convenience in design, and earthwork quantities figured from cross-sections plotted $1''$ to $10'$ are not reliable. For work on ordinary country roads, the $50'$ scale is generally adopted, using cross-sections plotted $1''$ to $5'$ or $1''$ to $4'$; this scale is satisfactory for laying the grade line and computing the earthwork.

The larger scales of $1'' = 20'$ or $1'' = 10'$ are useful in village work where a large amount of detail must be shown.

Plotting the center line.

The survey center line can be plotted by deflection angles at the *transit points*, using a table of natural tangents, a vernier

protractor or an ordinary paper protractor graduated to 15 minutes.

Where the center line has been well located in the field and there seems to be no necessity for a paper re-location, no great care need be taken in plotting the deflection angles, as in such a case the map serves more as a picture of the topographic features than as a basis for alignment.

Where a random line has been run in the field and some shifting of the center line is necessary, both angles and distances must be accurately plotted. If any extensive change of alignment is made, the new deflections and distances should be checked by figuring the difference of latitude and longitude for both the survey line and the office line between the points of equality.

Where the consideration of sight distance (see page 17) governs, Table No. 31 will be of service.

For convenience in plotting the topography, the 100′ survey stations are plainly marked.

The most common mistakes in plotting the map are made by reversing the deflection, as right instead of left and *vice versa*, or in adding or omitting 100′ in scaling long-tangent distances.

The work should be checked for mistakes of this nature.

All curve data is marked plainly on the map near the *P.I.* and shows

The deflection angle Δ
The degree of curve *D*
The radius of curve *R*
The tangent length *T*
The length of curve *L*
The station of the *P.I.*
The station of the *P.C.*
The station of the *P.T.*

If the curves have been figured in the office and have not been run in the field it is good practice to scale the offsets from the tangent to the curve and mark them on the map.

These offsets from the center line as run are then transferred to the cross-sections and the profile plotted from center line elevations on the cross-sections.

Table No. 31 gives the approximate distance that an automobile driver can see an approaching car, assuming that he is driving in the center of the macadam and that the approaching car is also in the center. Two distances are given for each curve, the first assuming that the line of sight is six feet from the ground, which is about right if the curve is on a straight grade, and makes the line of sight tangent to the cut slope of 1 on 1½ 19 feet off center for the narrow section shown in Fig. No. 7, page 30, and, second, assuming that the line of sight is close to the ground, as occurs on rounding the top of a hill, in which case the line of sight will be tangent to the side slope at, approximately, *11′ off center.*

TABLE 31

Degree of Curvature	Radius of Curve Feet	Sight Distance Case One. Feet	Sight Distance Case Two. Feet
5	1146.0	400	310
6	955.0	375	290
7	818.6	350	270
8	716.3	330	250
9	636.6	310	235
10	573.0	295	220
12	477.5	270	200
14	409.3	245	185
16	358.1	230	175
18	318.3	220	165
20	286.5	210	160
30	191.0	170	130
40	143.2	145	110
50	114.6	130	100

tting the topography.

f the topography has been recorded on a system of right-angle ets, as suggested and illustrated on page 123, it can be easily l quickly plotted by using the transparent le shown here.

This scale gives the plus distance along the vey base line, or center line, and the offset tance from the line in one operation.

As a general rule the plotting of the topog- hy need not be checked.

el Computations.

The survey computations of the Bench vels are checked and a list of bench eleva- 1s prepared; these elevations are used in ss-section level notes and from them the es are computed between benches. As h bench is reached these notes are cor- ted to agree with the elevation adopted that bench and then carried forward on corrected basis. The allowable error for ss-section levels, as mentioned in the chap- on surveys, is less than 0.1 feet. The cor- tion of the levels at each bench prevents r cumulative error and makes the eleva- 1s of the cross-section shots agree with adopted bench elevations with an error *less than 0.1′. This is as close as the*

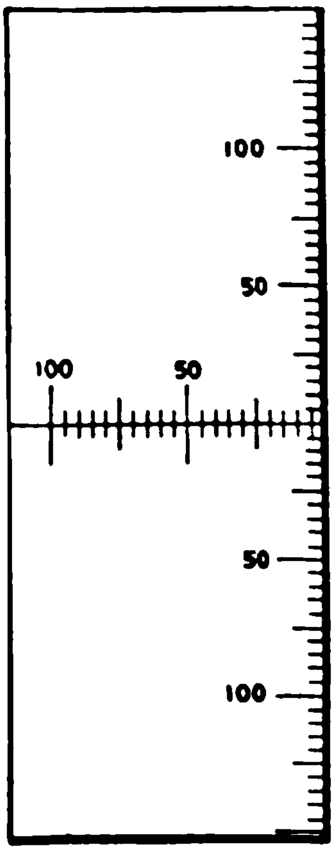


FIG. 59. — Convenient Transparent Scale for Plotting Topography

readings can be plotted and as close as they can be read in the field.

The computation of the bench levels and the adjustment of the cross-section notes should be checked by a competent man. The most common mistake in figuring the cross-section readings is to use the wrong height of instrument for a section. Such a mistake cannot be detected in plotting the sections, but is generally discovered when the profile is plotted.

In checking the notes particular care should be taken on this one point.

Plotting the cross-sections.

The cross-sections must be *very carefully* plotted, as the reliability of the earthwork computation depends largely on their accuracy.

The cross-section paper used should be exact in the divisions and should be printed or engraved from plates.

Ruled paper is inaccurate.

The plotting is checked by reliable men. Reading the shots back from the plotted cross-section is preferable to reading them from the book. The elevations of the center line and of the ditch line are written over the section. The station number or plus of each section is written on the right margin. The fact that the section has been graveled within the traveled way, that stone has been spread to a certain thickness, or any other fact that would influence the designer when laying a grade line, is noted on the section. See Fig. 60.

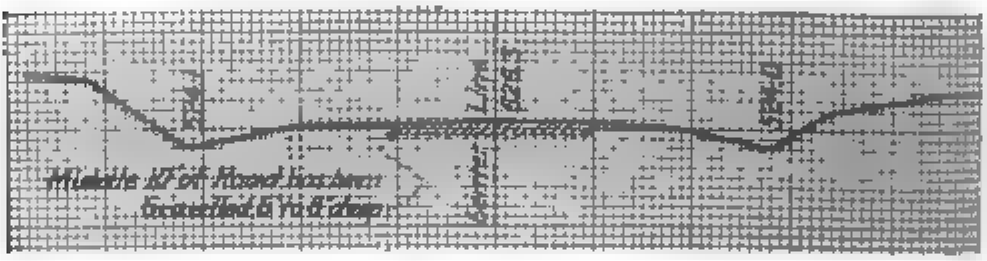


FIG 60

It is common practice to allow the inexperienced men to plot and check the cross-sections. We believe this is a mistake. This part of mapping is the most important of the preliminary plans, and the work should be plotted and checked so that the points are correct to the nearest 0.1 feet in elevation.

These points are then connected with a fine ink line.

Plotting the profile.

The profile is plotted from the center-line elevations given in *the cross-section* notes unless the proposed center line does not *coincide with* the survey center line, in which case the elevations

of the proposed line are projected from the previously plotted cross-sections.

It is not necessary to spend so much time for accuracy in plotting as on the sections, as the profile only serves as a guide in laying the grade line and no quantities depend upon its correctness. An error of .2 feet is allowable.

The elevation of each plotted center-line point is recorded with its stationing.

See Fig. 63.

The Design.

The completion of the profile finishes the preliminary mapping. The first operations of the office design are as follows:

A. The selection of section.

B. The depth of metalling.

C. The laying of the grade line.

These three points are so dependent on each other that they cannot be separated.

The most experienced man available should do this part of the work. He should be thoroughly familiar with the road from field inspection, and in designing he follows the general principles discussed in the chapters on Grades, Sections, and Foundations.

Shrinkage of Earthwork.

We have made no mention heretofore of the shrinkage of earth cut when placed in fill. This is an important factor of an economical grading design.

Trautwine states that for railroad work it takes

1.08 cu. yds. gravel or sand excavation to make 1 cu. yd. embankment.

1.10 cu. yds. clay excavation to make 1 cu. yd. embankment.

1.12 cu. yds. loam excavation to make 1 cu. yd. embankment.

1.15 cu. yds. vegetable surface soil excavation to make 1 cu. yd. embankment.

The quantities 1.08 cu. yds. gravel, etc., refer to the volume occupied by the material before removal.

Trautwine also states that in loosening earth and loading into wagons or cars 1 cu. yd. of earth swells about one-fifth and measures loose practically 1.2 cu. yds.

These values, however, cannot be used in roadwork, as a certain percentage of the excavation is sod or vegetable matter that is not suitable for embankment and must be wasted.

This waste material raises the percentage of cut necessary to make the fill.

The correct ratio for roadwork has been a source of contention among engineers, and we believe that the use of too high a value has resulted in a needless waste of thousands of dollars during the last five years in New York State alone.

Under this head it may be stated that on several roads under *the supervision of W. G.* Harger, a careful study of this point

was made, taking unusual care with the original and final cross-sections, the plotting and planimeter work, and it was found that for the cases investigated, the ratio of cut to fill varied from 1.15 in heavy cuts to 1.27 in light skimming work.

It is the general opinion among engineers of Division 5, N. Y. S. Dept. of Highways, that the percentage formerly used (namely 1.35) is too high. In nearly all cases where the work was at all heavy, a large excess of dirt had to be wasted. There have been some roads designed on a basis of 1.35 where more dirt was needed, but in the authors' opinion this was due to discrepancies in the field or office work or by allowing the contractor to use the roadbed excavation for filler or concrete material. If the soil encountered is suitable for such purposes, it is plainly up to the contractor to furnish other material for the places excavated.

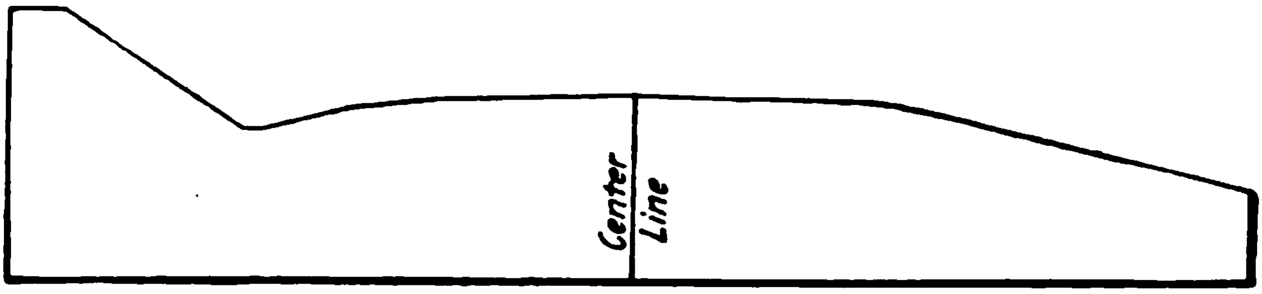


FIG. 61.—Transparent Templet for Use on Cross-Sections Giving Finished Shape of Road

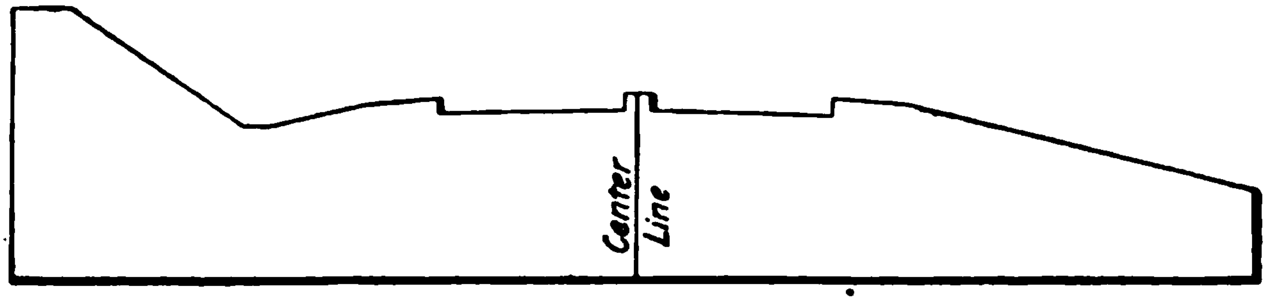


FIG. 62.—Transparent Templet with Stone Trench Cut; Saves Time in Drawing in Sections for Figuring Cut and Fill

The authors believe that the following ratios will be satisfactory for ordinary cases:

TABLE 32

Light skimming work, large amount of heavy sod	1.35
Light skimming work, considerable sod	1.30
Light skimming work, not much sod	1.25
Medium work	1.20
Heavy work	1.15

Trautwine's earth ratios are correct where earth borrow is obtained from a pit.

Trautwine states that 1.0 cu. yd. of solid rock, when broken up, will make 1.66 to 1.75 cu. yds. of rock fill.

In this statement he assumes that the fill is made of stone alone

and that the voids are not filled. In most roadwork, the small quantities of rock encountered are dumped in with the earth as embankment, and as the voids are all filled with earth it is evident that 1 cu. yd. of rock will make only 1 cu. yd. of fill; however, if a large unmixed stone fill is made, his ratio holds.

The discussion of these ratios has been carried out to some length because we believe it is one of the points that illustrate the advantage of careful engineering. Several of the New York State plans, the cost of which has ranged from $100 to $200 per mile, have been revised with this end in view; the revision costing an additional $15 to $30 per mile, with a resultant saving in construction cost of from $200 to $300 per mile.

The use of a rolling grade was recommended in the chapter on Grades. The designer is cautioned, however, not to carry this to extremes as there are many short, small hummocks which must be disregarded if a reasonably good profile is to be obtained. Fig. 62 A indicates a proper and improper use of an undulating profile.

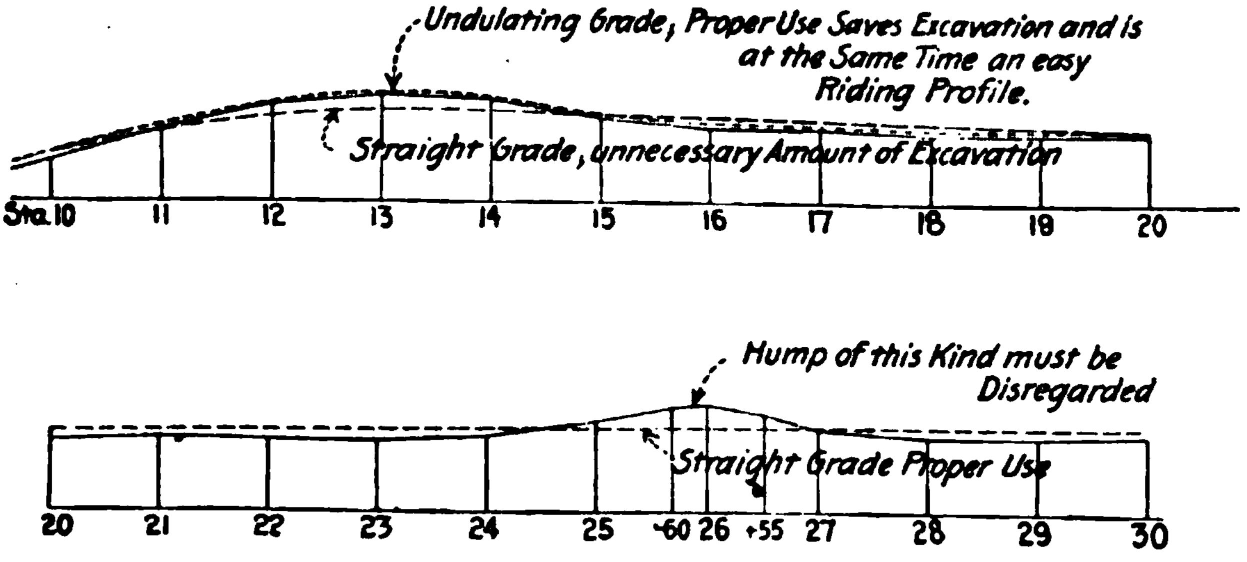


FIG. 62 A

Templets.

For the convenience of the designer in drawing the shape of the finished road on the cross-sections, a number of transparent composition templets are made, cut to proper scale, representing the different shaped sections to be used. See Figs. 61 and 62.

Economical Grade Line.

On page 12, the most economical grading conditions were mentioned. A convenient method of laying a grade line that will approximate these conditions is as follows: take the case of determining an economical profile for a road from station 11 to station 16, where the grade can be placed at any desired elevation (see page 12). Place the adopted templet on each cross-section so that the cut will just make the fill (this position i

estimated) and note the elevation of the center line of the proposed finished road for this position of the templet; mark this elevation on the profile for each section between stations 11 and 16; to connect these points would give the most economical grade line, but this can rarely be done with a resulting smooth profile. The adopted grade is obtained by drawing in a smooth grade line, that averages the elevations of these points and varies in elevation above or below them as little as possible.

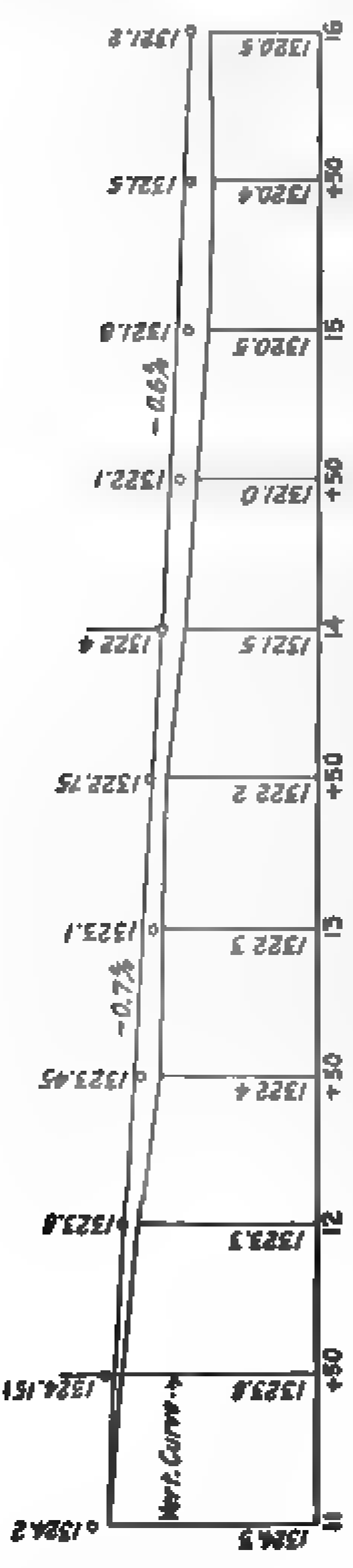


Fig. 63. — Sample Profile illustrating Method of Placing an Economical Grade Line

Note. — The small circles show the elevation of grade at each section that would make the proposed cut just make the proposed fill at that section.

The adopted grade elevation at each station is then figured, the shape of the finished road drawn on the cross-sections at these elevations, and the excavation and embankment computed. If the ratio of cut to fill is not correct, the grade is raised or lowered slightly to produce the desired ratio. This method is illustrated in Fig. 63.

For each stretch of road where economy of grading governs the profile, this procedure is repeated, and for the sections of road where other considerations govern, the grade is placed at the required elevation and the borrow, waste, or overhaul figured.

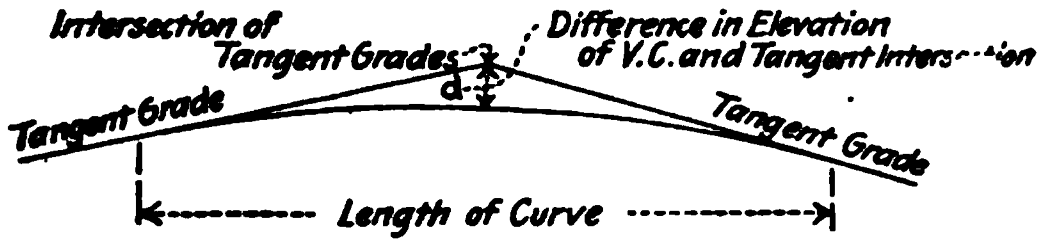
To obtain a smooth grade line vertical curves are used at the intersection of the different tangent rates of grade. Vertical curves are not usually used where the difference in rates of grade is less than 1 per cent.

For the final plans these vertical curve elevations may be computed by the following formulæ, but for the trial grade line they can be scaled from the profile, drawing in the curve by means of a regular curve templet, with which all modern offices are equipped.

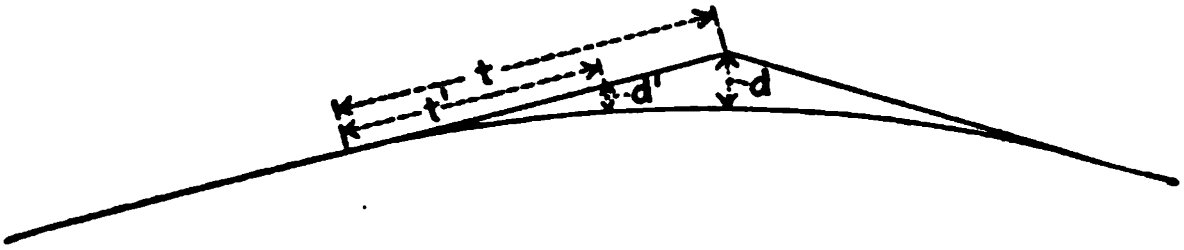
V. C. Formulæ:

Formula A. Difference in elevation at Center of Curve.

d expressed in feet $= \frac{1}{8}$ (Algebraic difference of the tangent grades expressed in feet per 100) $\times$ (length of curve expressed in stations of 100′).



FORMULA A

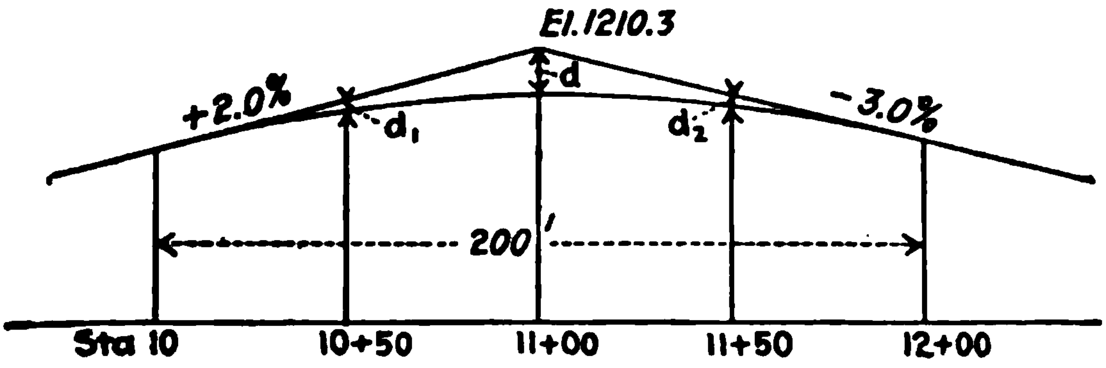


FORMULA B

Formula B. Intermediate differences of Elevations between tangent grades and points on vertical curve.

$$d' : d :: t'^2 : t^2$$

$$d' = \frac{dt'^2}{t^2}$$



EXAMPLE OF VERTICAL CURVE COMPUTATION

It is required to figure the vertical curve elevations for a vertical curve 200′ long between tangent grades of $+2.0\%$ and -3.0% meeting at station 11 + 00 at an elevation of 1210.3. First, find the middle correction d: use formula A.

$$d = \tfrac{1}{8}\,(2.0 - (-3.0)) \times (2)$$
$$d = \tfrac{1}{8}\,(5) \times (2) = \tfrac{10}{8} = 1.25'$$

Second, determine the corrections d_1 and d_2; use formula B.

$$d_1 = \frac{dt'^2}{t^2} = 1.25 \frac{50^2}{100^2} = 1.25 \times \tfrac{1}{4} = 0.31 \text{ feet}$$

$$d_2 = 1.25 \frac{50^2}{100^2} = 0.31 \text{ feet.}$$

Third, determine the elevation of the tangent grades at 10 + 50 and 11 + 50.

Fourth, subtract the *V.C.* corrections d_1, d, and d_2 from these tangent grades at 10 + 50, 11 + 00 and 11 + 50.

VERTICAL CURVE ELEVATIONS

Sta. 10 + 50 =	Tangent Elev.	1209.3	− 0.31	= 1208.99
" 11 + 00 =	" "	1210.3	− 1.25	= 1209.05
" 11 + 50 =	" "	1208.8	− 0.31	= 1208.49

The following table, No. 33, is useful for draftsmen in picking out the correct curve to use in inking in the vertical curves. This table is compiled for a horizontal scale of 1″ = 50′, and a vertical scale of 1″ = 10′. For other scales a similar table can be constructed.

Explanation of Table 33.

Suppose it is required to pick out the correct curve templet to draw in a vertical curve 300′ long between two tangent grades having an algebraic difference of 5 per cent (say a + 2.0 per cent grade and a − 3.0 per cent grade). On the line opposite 5.0 in column 1 representing the algebraic difference of rate, pick out the value 24 in the column headed 300′ curve; this means that a curve having a radius of 24 inches will fit the conditions. This curve can be found easily from the collection of curve templets which have been previously marked with their radii in inches.

The limit of sight due to vertical curves is shown in Table 34. Table 34 gives the distance ahead that a driver can see on a straight road, assuming that his eye is 6 feet above the road, for vertical curves of 200 feet, 150 feet, and 100 feet long between grades having a large difference of rate.

Example. Suppose a plus 5 percent grade meets a minus 7 per cent grade and that it is desired to put in the minimum length curve that will allow a sight ahead of 300 feet. The difference in gradient is 5 + 7 = 12 per cent. From table 34, opposite 12 per cent, we can readily pick the length required; it will be about 170 feet and 200 feet would probably be used. It is rare that the sight distance governs in the selection of length of curve.

Placing the Templets and Planimetering the Areas.

After the trial grade line has been placed the center line elevations of the proposed finished road are figured for each point on the profile where cross-sections have been taken and the section selected is drawn on the original cross-sections at these *elevations, using the* templets mentioned above.

Because it is comparatively easy to make a mistake of one

TABLE 33. TABLE OF RADII FOR PLOTTING VERTICAL CURVES ON PROFILES

Algebraic Diff.	100′ Curve Rad.	200′ Curve Rad.	300′ Curve Rad.	400′ Curve Rad.
1.0	40	80	120	160
1.2	33	67	100	132
1.4	29	57	85	116
1.6	25	50	75	100
1.8	22	44	65	88
2.0	20	40	60	80
2.2	18	36	55	72
2.4	16½	33	50	66
2.6	15½	30	46	62
2.8	14½	29	43	58
3.0	13½	27	40	54
3.2	12½	25	37	50
3.4	12	23	35	48
3.6	11	22	33	44
3.8	10½	21	32	42
4.0	10	20	30	40
4.5	9	18	27	36
5.0	8	16	24	32
5.5	7	14½	22	28
6.0	6½	13½	20	26
7.0	6	11½	17	24
8.0	5	10	16	20
9.0	4½	9	13½	18
10.0	4	8	12	16
11.0	3½	7	11	14½
12.0	3½	6½	10	13½
13.0	3	6	9	12½
14.0	3	5½	8½	11½

TABLE 34

Difference in Rate of Grades	Sight Distance for 200 ft. V. C.	Sight Distance for 150 ft. V. C.	Sight Distance for 100 ft. V. C.
8%	—	—	370 feet
10%	355 feet	315 feet	290 "
12%	320 "	290 "	260 "
14%	290 "	260 "	230 "
16%	260 "	230 "	210 "

foot or five feet in elevation, the elevation of new grade, as shown by the position of the templet, should be checked from the profile before computing the cuts and fills.

Because of the small, irregular shape of these areas it is not possible to compute them arithmetically and the areas are determined by planimeters. Great care must be exercised if the work is to be reliable; a double run is made and the second run should be twice the first area. A certain limit of error in the second area is adopted.[1] This method is sufficiently accurate for preliminary estimating. On final estimate work, where the payment for earth excavation depends on the planimeter work, a satisfactory method is to have two men, using separate planimeters, compute the areas independently without any knowledge of each other's result. If the amount of excavation as figured separately varies more than 2 per cent, a third run is made.

The reason that it is difficult to get accurate planimeter results is that the work is monotonous, confining, and hard on the eyes, and the tendency is toward carelessness unless the men know that their work is being checked.

The temptation is strong to make the second reading equal twice the first, and unless some such method is used to check up, small errors will be passed over.

As a matter of interest three miles of planimeter work, checked in this manner, was examined to see the average difference in areas, where two careful men using different planimeters computed their results separately.

The sections used were plotted 1″ = 5′; areas read to nearest 0.1 sq. ft.

The average percentage of difference for single areas were

1.	Small areas below 10 sq. ft.	......	per cent of difference	5%
2.	" " 10 to 30 " "	......	" " " "	2%
3.	Areas above 30 " "	......	" " " "	1%

However, these differences for single areas compensate, as some are above and some below the mean value, and computing the two separate results for the three miles gave the following result.

Percentage differences for work of two men for three miles, showing the reduction of error due to compensation.

1.	Small areas below 10 sq. ft.	....	per cent of difference	1.0 %
2.	" " 10 to 30 " "	....	" " " "	0.5 %
3.	Areas above 30 " "	....	" " " "	0.05 %

The average excavation per mile will run about 3,000 cu. yds., which means the average area of cut is about 16 sq. ft.

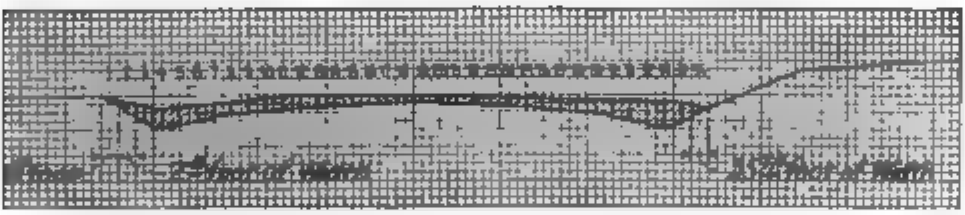
This comes under the second division and makes the probable error of final estimate planimeter work sufficiently close for all practical purposes.

Areas by measuring the depth of cut or fill at intervals of one foot across the section.

It is often necessary for the field men to make a change in grade *or alignment*, and the following method of estimating section areas

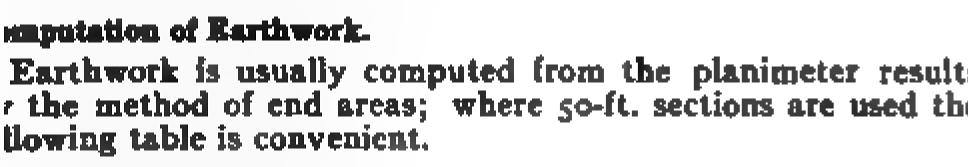
[1] *A satisfactory* rule has been to allow a difference of 0.4 sq. ft. for areas up to *50 sq. ft.*, and *1.0* sq. ft. error above 50 sq. ft.

convenient when no planimeter is available. The method is illus-
ated in the figures shown below:—



Measure the depth of the cutting on vertical No. 1. Call this pth 1′. It can be readily seen that this depth is the average depth r the first foot of the cross section, and if multiplied by one foot uals the area of the first foot of the section. In like manner easure the depth of the section on vertical No. 2. This is the erage depth of the second foot of the section, and multiplied by e foot equals the area of the second foot of the section. If the m of the depths 1′, 2′, 3′, etc., is obtained for the entire width of e section it is evident that the sum must equal the area of the ction.

This summation can readily be made graphically as shown below marking off on the edge of a piece of paper the successive depths.



Scale the distance from the reference mark to the end mark, using e same scale by which the cross section is plotted and the area of e section is obtained. This method is as reliable as planimeter ork, but is necessarily slower.

mputation of Earthwork.

Earthwork is usually computed from the planimeter results the method of end areas; where 50-ft. sections are used the llowing table is convenient.

planation of Table 35.

Suppose the area of excavation at, say, station 22 + 00 is .6 sq. ft.; suppose the excavation area at station 22 + 50 is .1 sq. ft. To get the number of cubic feet of excavation from ation 22 + 00 to 22 + 50 add 30.6 + 20.1 = 50.7. In Table an area of 50.7 gives an excavation quantity of 1267.5 cu. ft. here the normal cross-section interval is 50 ft. this table is a eat time-saver.

Table 36 is convenient in changing cubic feet to cubic yards.

Table 37 is convenient for preliminary estimates, as it gives e cubic yards directly for the sum of the end areas in square et. *It, however, is not* figured exactly and is not suitable for *al estimate work.*

TABLE 35 VOLUME OF 50-FT. SECTIONS IN CUBIC FEET FOR SUM OF END AREAS

COMPILED BY J. H. HUBER, ASSISTANT ENGINEER, BUFFALO, N.Y.

Sum of End Areas Sq. Ft.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	—	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5
1	25.0	27.5	30.0	32.5	35.0	37.5	40.0	42.5	45.0	47.5
2	50.0	52.5	55.0	57.5	60.0	62.5	65.0	67.5	70.0	72.5
3	75.0	77.5	80.0	82.5	85.0	87.5	90.0	92.5	95.0	97.5
4	100.0	102.5	105.0	107.5	110.0	112.5	115.0	117.5	120.0	122.5
5	125.0	127.5	130.0	132.5	135.0	137.5	140.0	142.5	145.0	147.5
6	150.0	152.5	155.0	157.5	160.0	162.5	165.0	167.5	170.0	172.5
7	175.0	177.5	180.0	182.5	185.0	187.5	190.0	192.5	195.0	197.5
8	200.0	202.5	205.0	207.5	210.0	212.5	215.0	217.5	220.0	222.5
9	225.0	227.5	230.0	232.5	235.0	237.5	240.0	242.5	245.0	247.5
10	250.0	252.5	255.0	257.5	260.0	262.5	265.0	267.5	270.0	272.5
11	275.0	277.5	280.0	282.5	285.0	287.5	290.0	292.5	295.0	297.5
12	300.0	302.5	305.0	307.5	310.0	312.5	315.0	317.5	320.0	322.5
13	325.0	327.5	330.0	332.5	335.0	337.5	340.0	342.5	345.0	347.5
14	350.0	352.5	355.0	357.5	360.0	362.5	365.0	367.5	370.0	372.5
15	375.0	377.5	380.0	382.5	385.0	387.5	390.0	392.5	395.0	397.5
16	400.0	402.5	405.0	407.5	410.0	412.5	415.0	417.5	420.0	422.5
17	425.0	427.5	430.0	432.5	435.0	437.5	440.0	442.5	445.0	447.5
18	450.0	452.5	455.0	457.5	460.0	462.5	465.0	467.5	470.0	472.5
19	475.0	477.5	480.0	482.5	485.0	487.5	490.0	492.5	495.0	497.5
20	500.0	502.5	505.0	507.5	510.0	512.5	515.0	517.5	520.0	522.5
21	525.0	527.5	530.0	532.5	535.0	537.5	540.0	542.5	545.0	547.5
22	550.0	552.5	555.0	557.5	560.0	562.5	565.0	567.5	570.0	572.5
23	575.0	577.5	580.0	582.5	585.0	587.5	590.0	592.5	595.0	597.5
24	600.0	602.5	605.0	607.5	610.0	612.5	615.0	617.5	620.0	622.5
25	625.0	627.5	630.0	632.5	635.0	637.5	640.0	642.5	645.0	647.5
26	650.0	652.5	655.0	657.5	660.0	662.5	665.0	667.5	670.0	672.5
27	675.0	677.5	680.0	682.5	685.0	687.5	690.0	692.5	695.0	697.5
28	700.0	702.5	705.0	707.5	710.0	712.5	715.0	717.5	720.0	722.5
29	725.0	727.5	730.0	732.5	735.0	737.5	740.0	742.5	745.0	747.5
30	750.0	752.5	755.0	757.5	760.0	762.5	765.0	767.5	770.0	772.5
31	775.0	777.5	780.0	782.5	785.0	787.5	790.0	792.5	795.0	797.5
32	800.0	802.5	805.0	807.5	810.0	812.5	815.0	817.5	820.0	822.5
33	825.0	827.5	830.0	832.5	835.0	837.5	840.0	842.5	845.0	847.5
34	850.0	852.5	855.0	857.5	860.0	862.5	865.0	867.5	870.0	872.5
35	875.0	877.5	880.0	882.5	885.0	887.5	890.0	892.5	895.0	897.5
36	900.0	902.5	905.0	907.5	910.0	912.5	915.0	917.5	920.0	922.5
37	925.0	927.5	930.0	932.5	935.0	937.5	940.0	942.5	945.0	947.5
38	950.0	952.5	955.0	957.5	960.0	962.5	965.0	967.5	970.0	972.5
39	975.0	977.5	980.0	982.5	985.0	987.5	990.0	992.5	995.0	997.5
40	1000.0	1002.5	1005.0	1007.5	1010.0	1012.5	1015.0	1017.5	1020.0	1022.5
41	1025.0	1027.5	1030.0	1032.5	1035.0	1037.5	1040.0	1042.5	1045.0	1047.5
42	1050.0	1052.5	1055.0	1057.5	1060.0	1062.5	1065.0	1067.5	1070.0	1072.5
43	1075.0	1077.5	1080.0	1082.5	1085.0	1087.5	1090.0	1092.5	1095.0	1097.5
44	1100.0	1102.5	1105.0	1107.5	1110.0	1112.5	1115.0	1117.5	1120.0	1122.5
45	1125.0	1127.5	1130.0	1132.5	1135.0	1137.5	1140.0	1142.5	1145.0	1147.5
46	1150.0	1152.5	1155.0	1157.5	1160.0	1162.5	1165.0	1167.5	1170.0	1172.5
47	1175.0	1177.5	1180.0	1182.5	1185.0	1187.5	1190.0	1192.5	1195.0	1197.5
48	1200.0	1202.5	1205.0	1207.5	1210.0	1212.5	1215.0	1217.5	1220.0	1222.5
49	1225.0	1227.5	1230.0	1232.5	1235.0	1237.5	1240.0	1242.5	1245.0	1247.5
50	1250.0	1252.5	1255.0	1257.5	1260.0	1262.5	1265.0	1267.5	1270.0	1272.5

NOTE. — For volumes larger than those given, use figures in the table, moving decimal point one place to the right and add proportional part.

TABLE 35. VOLUME OF 50-FT. SECTIONS IN CUBIC FEET FOR SUM OF END AREAS. — *Continued*

COMPILED BY J. H. HUBER, ASSISTANT ENGINEER, BUFFALO, N.Y.

Sum of End Areas Sq. Ft	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
50	1250.0	1252.5	1255.0	1257.5	1260.0	1262.5	1265.0	1267.5	1270.0	1272.5
51	1275.0	1277.5	1280.0	1282.5	1285.0	1287.5	1290.0	1292.5	1295.0	1297.5
52	1300.0	1302.5	1305.0	1307.5	1310.0	1312.5	1315.0	1317.5	1320.0	1322.5
53	1325.0	1327.5	1330.0	1332.5	1335.0	1337.5	1340.0	1342.5	1345.0	1347.5
54	1350.0	1352.5	1355.0	1357.5	1360.0	1362.5	1365.0	1367.5	1370.0	1372.5
55	1375.0	1377.5	1380.0	1382.5	1385.0	1387.5	1390.0	1392.5	1395.0	1397.5
56	1400.0	1402.5	1405.0	1407.5	1410.0	1412.5	1415.0	1417.5	1420.0	1422.5
57	1425.0	1427.5	1430.0	1432.5	1435.0	1437.5	1440.0	1442.5	1445.0	1447.5
58	1450.0	1452.5	1455.0	1457.5	1460.0	1462.5	1465.0	1467.5	1470.0	1472.5
59	1475.0	1477.5	1480.0	1482.5	1485.0	1487.5	1490.0	1492.5	1495.0	1497.5
60	1500.0	1502.5	1505.0	1507.5	1510.0	1512.5	1515.0	1517.5	1520.0	1522.5
61	1525.0	1527.5	1530.0	1532.5	1535.0	1537.5	1540.0	1542.5	1545.0	1547.5
62	1550.0	1552.5	1555.0	1557.5	1560.0	1562.5	1565.0	1567.5	1570.0	1572.5
63	1575.0	1577.5	1580.0	1582.5	1585.0	1587.5	1590.0	1592.5	1595.0	1597.5
64	1600.0	1602.5	1605.0	1607.5	1610.0	1612.5	1615.0	1617.5	1620.0	1622.5
65	1625.0	1627.5	1630.0	1632.5	1635.0	1637.5	1640.0	1642.5	1645.0	1647.5
66	1650.0	1652.5	1655.0	1657.5	1660.0	1662.5	1665.0	1667.5	1670.0	1672.5
67	1675.0	1677.5	1680.0	1682.5	1685.0	1687.5	1690.0	1692.5	1695.0	1697.5
68	1700.0	1702.5	1705.0	1707.5	1710.0	1712.5	1715.0	1717.5	1720.0	1722.5
69	1725.0	1727.5	1730.0	1732.5	1735.0	1737.5	1740.0	1742.5	1745.0	1747.5
70	1750.0	1752.5	1755.0	1757.5	1760.0	1762.5	1765.0	1767.5	1770.0	1772.5
71	1775.0	1777.5	1780.0	1782.5	1785.0	1787.5	1790.0	1792.5	1795.0	1797.5
72	1800.0	1802.5	1805.0	1807.5	1810.0	1812.5	1815.0	1817.5	1820.0	1822.5
73	1825.0	1827.5	1830.0	1832.5	1835.0	1837.5	1840.0	1842.5	1845.0	1847.5
74	1850.0	1852.5	1855.0	1857.5	1860.0	1862.5	1865.0	1867.5	1870.0	1872.5
75	1875.0	1877.5	1880.0	1882.5	1885.0	1887.5	1890.0	1892.5	1895.0	1897.5
76	1900.0	1902.5	1905.0	1907.5	1910.0	1912.5	1915.0	1917.5	1920.0	1922.5
77	1925.0	1927.5	1930.0	1932.5	1935.0	1937.5	1940.0	1942.5	1945.0	1947.5
78	1950.0	1952.5	1955.0	1957.5	1960.0	1962.5	1965.0	1967.5	1970.0	1972.5
79	1975.0	1977.5	1980.0	1982.5	1985.0	1987.5	1990.0	1992.5	1995.0	1997.5
80	2000.0	2002.5	2005.0	2007.5	2010.0	2012.5	2015.0	2017.5	2020.0	2022.5
81	2025.0	2027.5	2030.0	2032.5	2035.0	2037.5	2040.0	2042.5	2045.0	2047.5
82	2050.0	2052.5	2055.0	2057.5	2060.0	2062.5	2065.0	2067.5	2070.0	2072.5
83	2075.0	2077.5	2080.0	2082.5	2085.0	2087.5	2090.0	2092.5	2095.0	2097.5
84	2100.0	2102.5	2105.0	2107.5	2110.0	2112.5	2115.0	2117.5	2120.0	2122.5
85	2125.0	2127.5	2130.0	2132.5	2135.0	2137.5	2140.0	2142.5	2145.0	2147.5
86	2150.0	2152.5	2155.0	2157.5	2160.0	2162.5	2165.0	2167.5	2170.0	2172.5
87	2175.0	2177.5	2180.0	2182.5	2185.0	2187.5	2190.0	2192.5	2195.0	2197.5
88	2200.0	2202.5	2205.0	2207.5	2210.0	2212.5	2215.0	2217.5	2220.0	2222.5
89	2225.0	2227.5	2230.0	2232.5	2235.0	2237.5	2240.0	2242.5	2245.0	2247.5
90	2250.0	2252.5	2255.0	2257.5	2260.0	2262.5	2265.0	2267.5	2270.0	2272.5
91	2275.0	2277.5	2280.0	2282.5	2285.0	2287.5	2290.0	2292.5	2295.0	2297.5
92	2300.0	2302.5	2305.0	2307.5	2310.0	2312.5	2315.0	2317.5	2320.0	2322.5
93	2325.0	2327.5	2330.0	2332.5	2335.0	2337.5	2340.0	2342.5	2345.0	2347.5
94	2350.0	2352.5	2355.0	2357.5	2360.0	2362.5	2365.0	2367.5	2370.0	2372.5
95	2375.0	2377.5	2380.0	2382.5	2385.0	2387.5	2390.0	2392.5	2395.0	2397.5
96	2400.0	2402.5	2405.0	2407.5	2410.0	2412.5	2415.0	2417.5	2420.0	2422.5
97	2425.0	2427.5	2430.0	2432.5	2435.0	2437.5	2440.0	2442.5	2445.0	2447.5
98	2450.0	2452.5	2455.0	2457.5	2460.0	2462.5	2465.0	2467.5	2470.0	2472.5
99	2475.0	2477.5	2480.0	2482.5	2485.0	2487.5	2490.0	2492.5	2495.0	2497.5
100	2500.0	2502.5	2505.0	2507.5	2510.0	2512.5	2515.0	2517.5	2520.0	2522.5

PORTIONAL PART	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
		2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0

TABLE 36. CUBIC FEET AND CUBIC YARDS

0–1350		1350–2700		2700–4050		4050–5400	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
27	1	77	51	2,727	101	77	151
54	2	1,404	2	54	2	4,104	2
81	3	31	3	81	3	31	3
108	4	58	4	2,808	4	58	4
35	5	85	5	35	5	85	5
62	6	1,512	6	62	6	4,212	6
89	7	39	7	89	7	39	7
216	8	66	8	2,916	8	66	8
43	9	93	9	43	9	93	9
70	10	1,620	60	70	110	4,320	160
97	1	47	1	97	1	47	1
324	2	74	2	3,024	2	74	2
51	3	1,701	3	51	3	4,401	3
78	4	28	4	78	4	28	4
405	5	55	5	3,105	5	55	5
32	6	82	6	32	6	82	6
59	7	1,809	7	59	7	4,509	7
86	8	36	8	86	8	36	8
513	9	63	9	3,213	9	63	9
40	20	90	70	40	120	90	170
67	1	1,917	1	67	1	4,617	1
94	2	44	2	94	2	44	2
621	3	71	3	3,321	3	71	3
48	4	98	4	48	4	98	4
75	5	2,025	5	75	5	4,725	5
702	6	52	6	3,402	6	52	6
29	7	79	7	29	7	79	7
56	8	2,106	8	56	8	4,806	8
83	9	33	9	83	9	33	9
810	30	60	80	3,510	130	60	180
37	1	87	1	37	1	87	1
64	2	2,214	2	64	2	4,914	2
91	3	41	3	91	3	41	3
918	4	68	4	3,618	4	68	4
45	5	95	5	45	5	95	5
72	6	2,322	6	72	6	5,022	6
99	7	49	7	99	7	49	7
1,026	8	76	8	3,726	8	76	8
53	9	2,403	9	53	9	5,103	9
80	40	30	90	80	140	30	190
1,107	1	57	1	3,807	1	57	1
34	2	84	2	34	2	84	2
61	3	2,511	3	61	3	5,211	3
88	4	38	4	88	4	38	4
1,215	5	65	5	3,915	5	65	5
42	6	92	6	42	6	92	6
69	7	2,619	7	69	7	5,319	7
96	8	46	8	96	8	46	8
1,323	9	73	9	4,023	9	73	9
50	50	2,700	100	50	150	5,400	200

TABLE 36 — *continued*

6750	6750–8100		8100–9450		9450–10,800	
Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
201	77	251	8,127	301	77	351
2	6,804	2	54	2	9,504	2
3	31	3	81	3	31	3
4	58	4	8,208	4	58	4
5	85	5	35	5	85	5
6	6,912	6	62	6	9,612	6
7	39	7	89	7	39	7
8	66	8	8,316	8	66	8
9	93	9	43	9	93	9
210	7,020	260	70	310	9,720	360
1	47	1	97	1	47	1
2	74	2	8,424	2	74	2
3	7,101	3	51	3	9,801	3
4	28	4	78	4	28	4
5	55	5	8,505	5	55	5
6	82	6	32	6	82	6
7	7,209	7	59	7	9,909	7
8	36	8	86	8	36	8
9	63	9	8,613	9	63	9
220	90	270	40	320	90	370
1	7,317	1	67	1	10,017	1
2	44	2	94	2	44	2
3	71	3	8,721	3	71	3
4	98	4	48	4	98	4
5	7,425	5	75	5	10,125	5
6	52	6	8,802	6	52	6
7	79	7	29	7	79	7
8	7,506	8	56	8	10,206	8
9	33	9	83	9	33	9
230	60	280	8,910	330	60	380
1	87	1	37	1	87	1
2	7,614	2	64	2	10,314	2
3	41	3	91	3	41	3
4	68	4	9,018	4	68	4
5	95	5	45	5	95	5
6	7,722	6	72	6	10,422	6
7	49	7	99	7	49	7
8	76	8	9,126	8	76	8
9	7,803	9	53	9	10,503	9
240	30	290	80	340	30	390
1	57	1	9,207	1	57	1
2	84	2	34	2	84	2
3	7,911	3	61	3	10,611	3
4	38	4	88	4	38	4
5	65	5	9,315	5	65	5
6	92	6	42	6	92	6
7	8,019	7	69	7	10,719	7
8	46	8	96	8	46	8
9	73	9	9,423	9	73	9
250	8,100	300	50	350	10,800	400

TABLE 36 — *continued*

10,800–12,150		12,150–13,500		13,500–14,850		14,850–16,200	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
10,827	401	77	451	13,527	501	77	551
54	2	12,204	2	54	2	14,904	2
81	3	31	3	81	3	31	3
10,908	4	58	4	13,608	4	58	4
35	5	85	5	35	5	85	5
62	6	12,312	6	62	6	15,012	6
89	7	39	7	89	7	39	7
11,016	8	66	8	13,716	8	66	8
43	9	93	9	43	9	93	9
70	410	12,420	460	70	510	15,120	560
97	1	47	1	97	1	47	1
11,124	2	74	2	13,824	2	74	2
51	3	12,501	3	51	3	15,201	3
78	4	28	4	78	4	28	4
11,205	5	55	5	13,905	5	55	5
32	6	82	6	32	6	82	6
59	7	12,609	7	59	7	15,309	7
86	8	36	8	86	8	36	8
11,313	9	63	9	14,013	9	63	9
40	420	90	470	40	520	90	570
67	1	12,717	1	67	1	15,417	1
94	2	44	2	94	2	44	2
11,421	3	71	3	14,121	3	71	3
48	4	98	4	48	4	98	4
75	5	12,825	5	75	5	15,525	5
11,502	6	52	6	14,202	6	52	6
29	7	79	7	29	7	79	7
56	8	12,906	8	56	8	15,606	8
83	9	33	9	83	9	33	9
11,610	430	60	480	14,310	530	60	580
37	1	87	1	37	1	87	1
64	2	13,014	2	64	2	15,714	2
91	3	41	3	91	3	41	3
11,718	4	68	4	14,418	4	68	4
45	5	95	5	45	5	95	5
72	6	13,122	6	72	6	15,822	6
99	7	49	7	99	7	49	7
11,826	8	76	8	14,526	8	76	8
53	9	13,203	9	53	9	15,903	9
80	440	30	490	80	540	30	590
11,907	1	57	1	14,607	1	57	1
34	2	84	2	34	2	84	2
61	3	13,311	3	61	3	16,011	3
88	4	38	4	88	4	38	4
12,015	5	65	5	14,715	5	65	5
42	6	92	6	42	6	92	6
69	7	13,419	7	69	7	16,119	7
96	8	46	8	96	8	46	8
12,123	9	73	9	14,823	9	73	9
50	450	13,500	500	50	550	16,200	600

TABLE 36 — *continued*

…00–17,550		17,550–18,900		18,900–20,250		20,250–21,600	
	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
7	601	77	651	18,927	701	77	751
4	2	17,604	2	54	2	20,304	2
1	3	31	3	81	3	31	3
8	4	58	4	19,008	4	58	4
5	5	85	5	35	5	85	5
2	6	17,712	6	62	6	20,412	6
9	7	39	7	89	7	39	7
6	8	66	8	19,116	8	66	8
3	9	93	9	43	9	93	9
0	610	17,820	660	70	710	20,520	760
7	1	47	1	97	1	47	1
4	2	74	2	19,224	2	74	2
1	3	17,901	3	51	3	20,601	3
8	4	28	4	78	4	28	4
5	5	55	5	19,305	5	55	5
2	6	82	6	32	6	82	6
9	7	18,009	7	59	7	20,709	7
6	8	36	8	86	8	36	8
3	9	63	9	19,413	9	63	9
0	620	90	670	40	720	90	770
7	1	18,117	1	67	1	20,817	1
4	2	44	2	94	2	44	2
1	3	71	3	19,521	3	71	3
8	4	98	4	48	4	98	4
5	5	18,225	5	75	5	20,925	5
2	6	52	6	19,602	6	52	6
9	7	79	7	29	7	79	7
6	8	18,306	8	56	8	21,006	8
3	9	33	9	83	9	33	9
0	630	60	680	19,710	730	60	780
7	1	87	1	37	1	87	1
4	2	18,414	2	64	2	21,114	2
1	3	41	3	91	3	41	3
8	4	68	4	19,818	4	68	4
5	5	95	5	45	5	95	5
2	6	18,522	6	72	[illegible]	21,222	6
9	7	49	7	99	7	49	7
6	8	76	8	19,926	8	76	8
3	9	18,603	9	53	9	21,303	9
0	640	30	690	80	740	30	790
7	1	57	1	20,007	1	57	1
4	2	84	2	34	2	84	2
1	3	18,711	3	61	3	21,411	3
8	4	38	4	88	4	38	4
5	5	65	5	20,115	5	65	5
2	6	92	6	42	6	92	6
9	7	18,819	7	69	7	21,519	7
6	8	46	8	96	8	46	8
3	9	73	9	20,223	9	73	9
0	650	18,900	700	50	750	21,600	800

TABLE 36 — *continued*

21,600–22,950		22,950–24,300		24,300–25,650		25,650–27,000	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
21,627	801	77	851	24,327	901	77	951
54	2	23,004	2	54	2	25,704	2
81	3	31	3	81	3	31	3
21,708	4	58	4	24,408	4	58	4
35	5	85	5	35	5	85	5
62	6	23,112	6	62	6	25,812	6
89	7	39	7	89	7	39	7
21,816	8	66	8	24,516	8	66	8
43	9	93	9	43	9	93	9
70	810	23,220	860	70	910	25,920	960
97	1	47	1	97	1	47	1
21,924	2	74	2	24,624	2	74	2
51	3	23,301	3	51	3	26,001	3
78	4	28	4	78	4	28	4
22,005	5	55	5	24,705	5	55	5
32	6	82	6	32	6	82	6
59	7	23,409	7	59	7	26,109	7
86	8	36	8	86	8	36	8
22,113	9	63	9	24,813	9	63	9
40	820	90	870	40	920	90	970
67	1	23,517	1	67	1	26,217	1
94	2	44	2	94	2	44	2
22,221	3	71	3	24,921	3	71	3
48	4	98	4	48	4	98	4
75	5	23,625	5	75	5	26,325	5
22,302	6	52	6	25,002	6	52	6
29	7	79	7	29	7	79	7
56	8	23,706	8	56	8	26,406	8
83	9	33	9	83	9	33	9
22,410	830	60	880	25,110	930	60	980
37	1	87	1	37	1	87	1
64	2	23,814	2	64	2	26,514	2
91	3	41	3	91	3	41	3
22,518	4	68	4	25,218	4	68	4
45	5	95	5	45	5	95	5
72	6	23,922	6	72	6	26,622	6
99	7	49	7	99	7	49	7
22,626	8	76	8	25,326	8	76	8
53	9	24,003	9	53	9	26,703	9
80	840	30	890	80	940	30	990
22,707	1	57	1	25,407	1	57	1
34	2	84	2	34	2	84	2
61	3	24,111	3	61	3	26,811	3
88	4	38	4	88	4	38	4
22,815	5	65	5	25,515	5	65	5
42	6	92	6	42	6	92	6
69	7	24,219	7	69	7	26,919	7
96	8	46	8	96	8	46	8
22,923	9	73	9	25,623	9	73	9
50	850	24,300	900	50	950	27,000	1000

TABLE 36—*continued*

27,000–28,350		28,350–29,700		29,700–31,050		31,050–32,400	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
27,027	1001	77	1051	29,727	1101	77	1151
54	2	28,404	2	54	2	31,104	2
81	3	31	3	81	3	31	3
27,108	4	58	4	29,808	4	58	4
35	5	85	5	35	5	85	5
62	6	28,512	6	62	6	31,212	6
89	7	39	7	89	7	39	7
27,216	8	66	8	29,916	8	66	8
43	9	93	9	43	9	93	9
70	1010	28,620	1060	70	1110	31,320	1160
97	1	47	1	97	1	47	1
27,324	2	74	2	30,024	2	74	2
51	3	28,701	3	51	3	31,401	3
78	4	28	4	78	4	28	4
27,405	5	55	5	30,105	5	55	5
32	6	82	6	32	6	82	6
59	7	28,809	7	59	7	31,509	7
86	8	36	8	86	8	36	8
27,513	9	63	9	30,213	9	63	9
40	1020	90	1070	40	1120	90	1170
67	1	28,917	1	67	1	31,617	1
94	2	44	4	94	2	44	2
27,621	3	71	3	30,321	3	71	3
48	4	98	4	48	4	98	4
75	5	29,025	5	75	5	31,725	5
27,702	6	52	6	30,402	6	52	6
29	7	79	7	29	7	79	7
56	8	29,106	8	56	8	31,806	8
83	9	33	9	83	9	33	9
27,810	1030	60	1080	30,510	1130	60	1180
37	1	87	1	37	1	87	1
64	2	29,214	2	64	2	31,914	2
91	3	41	3	91	3	41	3
27,918	4	68	4	30,618	4	68	4
45	5	95	5	45	5	95	5
72	6	29,322	6	72	6	32,022	6
99	7	49	7	99	7	49	7
28,026	8	76	8	30,726	8	76	8
53	9	29,403	9	53	9	32,103	9
80	1040	30	1090	80	1140	30	1190
28,107	1	57	1	30,807	1	57	1
34	2	84	2	34	2	84	2
61	3	29,511	3	61	3	32,211	3
88	4	38	4	88	4	38	4
28,215	5	65	5	30,915	5	65	5
42	6	92	6	42	6	92	6
69	7	29,619	7	69	7	32,319	7
96	8	46	8	96	8	46	8
28,323	9	73	9	31,023	9	73	9
50	1050	29,700	1100	50	1150	32,400	1200

TABLE 36 — *continued*

32,400–33,750		33,750–35,100		35,100–36,450		36,450–37,80	
Feet	Yds.	Feet	Yds.	Feet	Yds.	Feet	Y
32,427	1201	77	1251	35,127	1301	77	13
54	2	33,804	2	54	2	36,504	
81	3	31	3	81	3	31	
32,508	4	58	4	35,208	4	58	
35	5	85	5	35	5	85	
62	6	33,912	6	62	6	36,612	
89	7	39	7	89	7	39	
32,616	8	66	8	35,316	8	66	
43	9	93	9	43	9	93	
70	1210	34,020	1260	70	1310	36,720	13
97	1	47	1	97	1	47	
32,724	2	74	2	35,424	2	74	
51	3	34,101	3	51	3	36,801	
78	4	28	4	78	4	28	
32,805	5	55	5	35,505	5	55	
32	6	82	6	32	6	82	
59	7	34,209	7	59	7	36,909	
86	8	36	8	86	8	36	
32,913	9	63	9	35,613	9	63	
40	1220	90	1270	40	1320	90	13
67	1	34,317	1	67	1	37,017	
94	2	44	2	94	2	44	
33,021	3	71	3	35,721	3	71	
48	4	98	4	48	4	98	
75	5	34,425	5	75	5	37,125	
33,102	6	52	6	35,802	6	52	
29	7	79	7	29	7	79	
56	8	34,506	8	56	8	37,206	
83	9	33	9	83	9	33	
33,210	1230	60	1280	35,910	1330	60	13
37	1	87	1	37	1	87	
64	2	34,614	2	64	2	37,314	
91	3	41	3	91	3	41	
33,318	4	68	4	36,018	4	68	
45	5	95	5	45	5	95	
72	6	34,722	6	72	6	37,422	
99	7	49	7	99	7	49	
33,426	8	76	8	36,126	8	76	
53	9	34,803	9	53	9	37,503	
80	1240	30	1290	80	1340	30	13
33,507	1	57	1	36,207	1	57	
34	2	84	2	34	2	84	
61	3	34,911	3	61	3	37,611	
88	4	38	4	88	4	38	
33,615	5	65	5	36,315	5	65	
42	6	92	6	42	6	92	
69	7	35,019	7	69	7	37,719	
96	8	46	8	96	8	46	
33,723	9	73	9	36,423	9	73	
50	1250	35,100	1300	50	1350	37,800	1

TABLE 36 — *continued*

–39,150	39,150–40,500		40,500–41,850		41,850–43,200	
Yds.	Feet	Yds.	Feet	Yds.	Feet	Yds.
1401	77	1451	40,527	1501	77	1551
2	39,204	2	54	2	41,904	2
3	31	3	81	3	31	3
4	58	4	40,608	4	58	4
5	85	5	35	5	85	5
6	39,312	6	62	6	42,012	6
7	39	7	89	7	39	7
8	66	8	40,716	8	66	8
9	93	9	43	9	93	9
1410	39,420	1460	70	1510	42,120	1560
1	47	1	97	1	47	1
2	74	2	40,824	2	74	2
3	39,501	3	51	3	42,201	3
4	28	4	78	4	28	4
5	55	5	40,905	5	55	5
6	82	6	32	6	82	6
7	39,609	7	59	7	42,309	7
8	36	8	86	8	36	8
9	63	9	41,013	9	63	9
1420	90	1470	40	1520	90	1570
1	39,717	1	67	1	42,417	1
2	44	2	94	2	44	2
3	71	3	41,121	3	71	3
4	98	4	48	4	98	4
5	39,825	5	75	5	42,525	5
6	52	6	41,202	6	52	6
7	79	7	29	7	79	7
8	39,906	8	56	8	42,606	8
9	33	9	83	9	33	9
1430	60	1480	41,310	1530	60	1580
1	87	1	37	1	87	1
2	40,014	2	64	2	42,714	2
3	41	3	91	3	41	3
4	68	4	41,418	4	68	4
5	95	5	45	5	95	5
6	40,122	6	72	6	42,822	6
7	49	7	99	7	49	7
8	76	8	41,526	8	76	8
9	40,203	9	53	9	42,903	9
1440	30	1490	80	1540	30	1590
1	57	1	41,607	1	57	1
2	84	2	34	2	84	2
3	40,311	3	61	3	43,011	3
4	38	4	88	4	38	4
5	65	5	41,715	5	65	5
6	92	6	42	6	92	6
7	40,419	7	69	7	43,119	7
8	46	8	96	8	46	8
9	73	9	41,823	9	73	9
1450	40,500	1500	50	1550	43,200	1600

Table 37. New York State Department of Highways.
Earthwork Computation Tables

Distance Horizontal Sum of Areas Vertical Quantities in Cubic Yards

2	3	4	5	6	7	8	9	10	11	12	13	14	D'nce Areas
0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	1.0
0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	2
0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	4
0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	6
0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	8
0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	2.0
0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	2
0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	4
0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	6
0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	8
0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.7	0.8	3.0
0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	2
0.1	0.2	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	4
0.1	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	6
0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	8
0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.0	4.0
0.1	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	2
0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.1	4
0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	6
0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.2	8
0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	5.0
0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	2
0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	4
0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	6
0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	8
0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.6	6.0
0.2	0.3	0.5	0.6	0.7	0.8	0.9	1.1	1.1	1.3	1.4	1.5	1.6	2
0.2	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.7	4
0.2	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.5	1.5	1.7	6
0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.8	8
0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.8	7.0
0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2
0.3	0.4	0.5	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6	1.8	1.9	4
0.3	0.4	0.6	0.7	0.8	1.0	1.1	1.3	1.4	1.5	1.7	1.8	2.0	6
0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.9	2.0	8
0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.8	1.9	2.1	8.0
0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2
0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.9	2.0	2.2	4
0.3	0.5	0.6	0.8	1.0	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.2	6
0.3	0.5	0.7	0.8	1.0	1.1	1.3	1.5	1.6	1.8	2.0	2.1	2.3	8
0.3	0.5	0.7	0.9	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	9.0
0.3	0.5	0.7	0.9	1.0	1.2	1.3	1.5	1.7	1.9	2.0	2.2	2.4	2
0.3	0.5	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.4	4
0.4	0.5	0.7	0.9	1.1	1.2	1.4	1.6	1.8	2.0	2.1	2.3	2.5	6
0.4	0.5	0.7	0.9	1.1	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.5	8
0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.0	2.2	2.4	2.6	10.0
0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	1.9	2.1	2.3	2.5	2.7	5
0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	11.0
0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.8	3.0	5
0.4	0.7	0.9	1.1	1.3	1.6	1.8	2.0	2.2	2.4	2.7	2.9	3.1	12.0
0.5	0.7	0.9	1.2	1.4	1.6	1.9	2.1	2.3	2.5	2.8	3.0	3.2	5
0.5	0.7	1.0	1.2	1.5	1.7	2.0	2.2	2.4	2.6	2.9	3.1	3.4	13.0
0.5	0.7	1.0	1.3	1.5	1.8	2.0	2.3	2.5	2.7	3.0	3.3	3.5	5
0.5	0.8	1.0	1.3	1.6	1.8	2.1	2.3	2.6	2.8	3.1	3.4	3.6	14.0

ABLE 37. NEW YORK STATE DEPARTMENT OF HIGHWAYS.
EARTHWORK COMPUTATION TABLES. — *continued*

ANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

16	17	18	19	20	21	22	23	24	25	26	27	D'uble Areas
0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	1.0
0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	2
0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	4
0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	6
0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	8
0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	2.0
0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1	1.1	2
0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	4
0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	6
0.8	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	8
0.9	0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	3.0
0.9	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6	2
1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7	4
1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.7	1.8	6
1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.8	1.9	8
1.2	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	4.0
1.2	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2
1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	4
1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	6
1.4	1.5	1.6	1.7	1.8	1.8	2.0	2.0	2.1	2.2	2.3	2.4	8
1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.5	5.0
1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2
1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	4
1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	6
1.7	1.8	2.0	2.0	2.1	2.3	2.4	2.5	2.6	2.7	2.8	2.9	8
1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.0	6.0
1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	2
1.9	2.0	2.1	2.2	2.4	2.5	2.6	2.7	2.8	3.0	3.1	3.2	4
2.0	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	6
2.0	2.1	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.4	8
2.1	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	7.0
2.1	2.3	2.4	2.5	2.7	2.8	2.9	3.1	3.2	3.3	3.5	3.6	2
2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.3	3.4	3.6	3.7	4
2.3	2.4	2.5	2.7	2.8	3.0	3.1	3.2	3.4	3.5	3.7	3.8	6
2.3	2.5	2.6	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.8	3.9	8
2.4	2.5	2.7	2.8	3.0	3.1	3.3	3.4	3.6	3.7	3.9	4.0	8.0
2.4	2.6	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.8	4.0	4.1	2
2.5	2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.7	3.9	4.[illegible]	4.2	4
2.5	2.7	2.9	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.[illegible]	4.3	6
2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.8	3.9	4.1	4[illegible]	4.4	8
2.7	2.8	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.2	4[illegible]	4.5	9.0
2.7	2.9	3.1	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.[illegible]	4.6	2
2.8	3.0	3.1	3.3	3.5	3.7	3.8	4.0	4.2	4.4	4.[illegible]	4.7	4
2.8	3.0	3.2	3.4	3.6	3.7	3.9	4.1	4.3	4.5	4.[illegible]	4.8	6
2.9	3.1	3.3	3.4	3.6	3.8	4.0	4.2	4.4	4.5	4.7	4.9	8
3.0	3.1	3.3	3.5	3.7	3.9	4.1	4.2	4.4	4.6	4.8	5.0	100
3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.6	4.9	5.0	5.3	5
3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	11.0
3.4	3.6	3.8	4.0	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5
3.6	3.8	4.0	4.2	4.5	4.7	4.9	5.1	5.3	5.5	5.8	6.0	12.0
3.7	3.9	4.1	4.4	4.6	4.9	5.1	5.3	5.5	5.8	6.0	6.2	5
3.8	4.1	4.3	4.6	4.8	5.0	5.3	5.5	5.8	6.0	6.3	6.5	13.0
4.0	4.2	4.5	4.8	5.0	5.2	5.5	5.8	6.0	6.3	6.5	6.7	[illegible]
4.2	4.4	4.7	4.9	5.2	5.4	5.7	6.0	6.2	6.5	6.7	7.0	[illegible]

TABLE 37.—*continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

28	29	30	31	32	33	34	35	36	37	38	39	40	D'[illegible] Area
0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	1.0
0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	2
0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	4
0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2	6
0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.3	8
1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	2.0
1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6	2
1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	4
1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	6
1.5	1.5	1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.1	8
1.6	1.6	1.7	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.2	3.0
1.7	1.7	1.8	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2
1.8	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	4
1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	6
2.0	2.0	2.1	2.2	2.3	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	8
2.1	2.2	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.9	3.0	4.0
2.2	2.3	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.0	3.1	2
2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.3	4
2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.2	3.3	3.4	6
2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	8
2.6	2.7	2.8	2.9	3.0	3.1	3.1	3.2	3.3	3.4	3.5	3.6	3.7	5.0
2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	2
2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4
2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.1	4.2	6
3.0	3.1	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	8
3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.5	6.0
3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.3	4.4	4.5	4.6	2
3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.6	4.7	4
3.4	3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	6
3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.0	8
3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	7.0
3.7	3.9	4.0	4.1	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.3	2
3.8	4.0	4.1	4.3	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.4	5.5	4
3.9	4.1	4.2	4.4	4.5	4.7	4.8	4.9	5.1	5.2	5.4	5.5	5.6	6
4.0	4.2	4.3	4.5	4.6	4.8	4.9	5.1	5.2	5.4	5.5	5.6	5.8	8
4.2	4.3	4.4	4.6	4.7	4.9	5.0	5.2	5.3	5.5	5.6	5.8	5.9	8.0
4.3	4.4	4.6	4.7	4.9	5.0	5.2	5.3	5.5	5.6	5.8	5.9	6.1	2
4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.5	5.6	5.8	5.9	6.1	6.2	4
4.5	4.6	4.8	4.9	5.1	5.3	5.4	5.6	5.7	5.9	6.1	6.2	6.4	6
4.6	4.7	4.9	5.1	5.2	5.4	5.5	5.7	5.9	6.0	6.2	6.4	6.5	8
4.7	4.8	5.0	5.2	5.3	5.5	5.7	5.8	6.0	6.2	6.3	6.5	6.7	9.0
4.8	4.9	5.1	5.3	5.5	5.6	5.8	6.0	6.1	6.3	6.5	6.7	6.8	2
4.9	5.1	5.2	5.4	5.6	5.8	5.9	6.1	6.3	6.5	6.6	6.8	7.0	4
5.0	5.2	5.3	5.5	5.7	5.9	6.1	6.2	6.4	6.6	6.8	6.9	7.1	6
5.1	5.3	5.5	5.6	5.8	6.0	6.2	6.3	6.5	6.7	6.9	7.1	7.3	8
5.2	5.3	5.6	5.8	5.9	6.1	6.3	6.5	6.7	6.9	7.0	7.2	7.4	10.0
5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	5
5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.8	7.9	8.1	11.0
6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.5	7.7	7.9	8.1	8.3	8.5	5
6.2	6.4	6.7	7.0	7.1	7.3	7.6	7.8	8.0	8.2	8.5	8.7	8.9	12.0
6.5	6.7	7.0	7.2	7.4	7.7	7.9	8.1	8.3	8.6	8.8	9.0	9.3	5
6.7	7.0	7.2	7.5	7.7	8.0	8.2	8.4	8.7	8.9	9.2	9.4	9.6	13.0
7.0	7.3	7.5	7.8	8.0	8.3	8.5	8.8	9.0	9.3	9.5	9.8	10.0	5
7.2	7.5	7.8	8.0	8.3	8.6	8.8	9.1	9.3	9.6	9.8	10.1	10.4	14.0

TABLE 37. — *continued*

ANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

42	43	44	45	46	47	48	49	50	75	100	D'uble Areas
0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.4	1.9	1.0
0.9	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.6	2.2	2
1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.9	2.6	4
1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.5	2.2	3.0	6
1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.7	2.5	3.3	8
1.6	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8	2.8	3.7	2.0
1.7	1.8	1.8	1.8	1.9	1.9	2.0	2.0	2.0	3.1	4.1	2
1.9	1.9	2.0	2.0	2.0	2.1	2.1	2.2	2.2	3.5	4.4	4
2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	3.6	4.8	6
2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.6	3.9	5.2	8
2.3	2.4	2.4	2.5	2.6	2.6	2.7	2.7	2.8	4.2	5.6	3.0
2.5	2.6	2.6	2.7	2.7	2.8	2.9	2.9	3.0	4.4	5.9	2
2.6	2.7	2.8	2.8	2.9	3.0	3.0	3.1	3.2	4.7	6.3	4
2.8	2.9	2.9	3.0	3.1	3.1	3.2	3.3	3.3	5.0	6.7	6
3.0	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.5	5.3	7.0	8
3.1	3.2	3.3	3.3	3.4	3.5	3.6	3.6	3.7	5.6	7.4	4.0
3.3	3.4	3.4	3.5	3.6	3.7	3.7	3.8	3.9	5.9	7.9	2
3.4	3.5	3.6	3.7	3.8	3.8	3.9	4.0	4.1	6.1	8.2	4
3.6	3.7	3.8	3.8	3.9	4.0	4.1	4.2	4.3	6.4	8.5	6
3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	6.7	8.9	8
3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.5	4.6	7.0	9.3	5.0
4.1	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	7.2	9.7	2
4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	7.5	10.0	4
4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	7.8	0.4	6
4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.4	8.1	0.8	8
4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.6	8.3	1.1	6.0
4.8	4.9	5.0	5.2	5.3	5.4	5.5	5.6	5.7	8.6	1.5	2
5.0	5.1	5.2	5.3	5.5	5.6	5.7	5.8	5.9	8.9	1.8	4
5.1	5.2	5.4	5.5	5.6	5.7	5.9	6.0	6.1	9.2	2.2	6
5.3	5.4	5.5	5.7	5.8	5.9	6.0	6.2	6.3	9.5	2.6	8
5.4	5.6	5.7	5.8	5.9	6.1	6.2	6.3	6.5	9.7	3.0	7.0
5.6	5.7	5.8	6.0	6.1	6.3	6.4	6.5	6.7	10.0	3.4	2
5.7	5.9	6.0	6.2	6.3	6.4	6.6	6.7	6.8	0.3	3.7	4
5.9	6.0	6.2	6.3	6.5	6.6	6.7	6.9	7.0	0.6	4.1	6
6.1	6.2	6.3	6.5	6.6	6.8	6.9	7.1	7.2	0.8	4.4	8
6.2	6.4	6.5	6.7	6.8	7.0	7.1	7.2	7.4	11.1	4.8	8.0
6.3	6.5	6.6	6.8	7.0	7.1	7.3	7.4	7.6	1.4	5.2	2
6.5	6.7	6.8	7.0	7.2	7.3	7.5	7.6	7.8	1.7	5.6	4
6.7	6.8	7.0	7.2	7.3	7.5	7.7	7.8	8.0	2.0	6.0	6
6.9	7.0	7.2	7.3	7.5	7.7	7.8	8.0	8.2	2.2	6.3	8
7.0	7.2	7.3	7.5	7.7	7.8	8.0	8.2	8.3	12.5	6.6	9.0
7.2	7.3	7.5	7.7	7.8	8.0	8.2	8.3	8.5	2.8	7.0	2
7.3	7.5	7.7	7.8	8.0	8.2	8.4	8.5	8.7	3.1	7.4	4
7.5	7.6	7.8	8.0	8.2	8.3	8.5	8.7	8.9	3.3	7.8	6
7.6	7.8	8.0	8.2	8.4	8.5	8.7	8.9	9.1	3.6	8.2	8
7.8	8.0	8.1	8.3	8.5	8.7	8.9	9.1	9.3	13.9	8.5	10.0
8.2	8.4	8.6	8.8	8.9	9.1	9.3	9.5	9.7	4.6	9.5	5
8.5	8.7	8.9	9.2	9.4	9.6	9.8	10.0	10.2	5.3	20.3	11.0
8.9	9.1	9.4	9.6	9.8	10.0	10.2	0.4	0.7	6.0	1.3	5
9.3	9.5	9.8	10.0	10.2	0.4	0.7	0.9	1.1	6.7	2.2	12.0
9.7	10.0	10.2	10.4	10.6	10.8	11.1	11.4	11.6	17.4	23.1	5
10.1	0.4	0.6	0.8	1.1	1.3	1.6	1.8	2.1	8.0	4.1	13.0
0.5	0.8	1.0	1.1	1.5	1.8	2.0	2.3	2.5	8.8	5.0	5
0.9	1.2	1.4	1.7	1.9	2.2	2.4	2.7	3.0	9.4	6.0	14.0

TABLE 37. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

2	3	4	5	6	7	8	9	10	11	12	13	14	D'[illegible] Area
0.5	0.8	1.1	1.3	1.6	1.9	2.1	2.4	2.7	3.0	3.2	3.5	3.8	14.5
0.6	0.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.1	3.3	3.6	3.9	15.0
0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	2.9	3.2	3.4	3.7	4.0	5
0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.6	3.8	4.1	16.0
0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.1	3.4	3.7	4.0	4.3	5
0.6	0.9	1.3	1.6	1.9	2.2	2.5	2.8	3.1	3.5	3.8	4.1	4.4	17.0
0.6	1.0	1.3	1.6	2.0	2.3	2.6	2.9	3.2	3.6	3.9	4.2	4.5	5
0.7	1.0	1.5	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	18.0
0.7	1.0	1.4	1.7	2.1	2.4	2.7	3.1	3.4	3.8	4.1	4.4	4.8	5
0.7	1.1	1.4	1.8	2.1	2.5	2.8	3.2	3.5	3.9	4.2	4.6	4.9	19.0
0.7	1.1	1.4	1.8	2.2	2.5	2.9	3.2	3.6	4.0	4.3	4.7	5.0	5
0.7	1.1	1.5	1.9	2.2	2.6	3.0	3.3	3.7	4.1	4.4	4.8	5.2	20.0
0.8	1.2	1.6	2.0	2.3	2.7	3.1	3.5	3.9	4.3	4.7	5.1	5.4	1
0.8	1.2	1.6	2.0	2.4	2.8	3.3	3.7	4.1	4.5	4.9	5.3	5.7	2
0.9	1.3	1.7	2.1	2.6	3.0	3.4	3.8	4.3	4.7	5.1	5.5	6.0	3
0.9	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.4	4.9	5.3	5.8	6.2	4
0.9	1.4	1.9	2.3	2.8	3.2	3.7	4.2	4.6	5.1	5.6	6.0	6.5	25.0
1.0	1.4	1.9	2.4	2.9	3.4	3.9	4.3	4.8	5.3	5.8	6.3	6.7	6
1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7
1.0	1.6	2.1	2.6	3.1	3.6	4.2	4.7	5.2	5.7	6.2	6.7	7.3	8
1.1	1.6	2.1	2.7	3.2	3.8	4.3	4.8	5.4	5.9	6.4	7.0	7.5	9
1.1	1.7	2.2	2.8	3.3	3.9	4.4	5.0	5.5	6.1	6.7	7.2	7.8	30.0
1.2	1.7	2.3	2.9	3.4	4.0	4.6	5.2	5.7	6.3	6.9	7.5	8.0	1
1.2	1.8	2.4	3.0	3.6	4.2	4.7	5.3	6.0	6.5	7.1	7.7	8.3	2
1.2	1.8	2.4	3.0	3.7	4.3	4.9	5.5	6.1	6.7	7.3	8.0	8.6	3
1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.7	6.3	6.9	7.5	8.2	8.8	4
1.3	1.9	2.6	3.2	3.9	4.5	5.2	5.8	6.5	7.1	7.8	8.4	9.1	35.0
1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	6
1.4	2.1	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.5	8.2	8.9	9.6	7
1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7.0	7.7	8.4	9.1	9.8	8
1.4	2.2	2.9	3.6	4.3	5.0	5.8	6.5	7.2	7.9	8.7	9.4	10.1	9
1.5	2.2	3.0	3.7	4.4	5.2	5.9	6.7	7.4	8.1	8.9	9.7	0.4	40.0
1.5	2.3	3.0	3.8	4.5	5.3	6.1	6.8	7.6	8.3	9.1	9.9	0.6	1
1.6	2.3	3.1	3.9	4.7	5.4	6.2	7.0	7.8	8.5	9.3	10.1	0.9	2
1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	8.8	9.6	10.4	1.2	3
1.6	2.4	3.3	4.1	4.9	5.7	6.5	7.3	8.2	9.0	9.8	10.6	11.4	4
1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0	0.9	1.7	45.0
1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5	9.4	0.2	1.1	1.9	6
1.7	2.6	3.5	4.3	5.2	6.1	7.0	7.8	8.7	9.6	0.5	1.3	2.1	7
1.8	2.7	3.6	4.4	5.3	6.2	7.1	8.0	8.9	9.8	0.7	1.6	2.4	8
1.8	2.7	3.6	4.5	5.4	6.3	7.3	8.2	9.1	10.0	10.9	11.8	12.7	9
1.8	2.8	3.7	4.6	5.6	6.5	7.4	8.3	9.3	0.2	1.1	2.1	3.0	50.0
1.9	2.9	3.9	4.8	5.8	6.7	7.7	8.7	9.6	0.6	1.6	2.5	3.5	2
2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	1.0	2.0	3.0	4.0	4
2.1	3.1	4.1	5.2	6.2	7.3	8.3	9.3	0.4	1.4	2.5	3.5	4.5	6
2.2	3.2	4.3	5.4	6.4	7.5	8.6	9.7	10.7	11.8	12.9	13.9	15.0	8
2.2	3.3	4.4	5.5	6.7	7.8	8.9	10.0	1.1	2.2	3.3	4.4	5.5	60.0
2.3	3.4	4.6	5.7	6.9	8.0	9.2	0.3	1.5	2.6	3.8	4.9	6.1	2
2.4	3.6	4.7	5.9	7.1	8.3	9.5	0.7	1.9	3.0	4.2	5.4	6.6	4
2.4	3.7	4.9	6.1	7.3	8.6	9.8	1.0	2.2	3.4	4.7	5.9	7.1	6
2.5	3.8	5.0	6.3	7.5	8.8	10.1	11.4	12.6	13.8	15.1	16.4	17.6	8
2.6	3.9	5.2	6.5	7.8	9.1	10.4	1.7	3.0	4.3	5.5	6.8	8.2	70.0
2.7	4.0	5.3	6.7	8.0	9.3	10.7	2.0	3.4	4.7	6.0	7.3	8.6	2
[illegible]	4.1	5.5	6.9	8.2	9.6	10.0	2.3	3.7	5.1	6.5	7.8	9.2	4

TABLE 37.—*continued*

ANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

	16	17	18	19	20	21	22	23	24	25	26	27	D'uble Areas
.0	4.3	4.6	4.8	5.1	5.1	5.6	5.9	6.2	6.5	6.7	6.9	7.3	14.5
2	4.4	4.7	5.0	5.3	5.6	5.8	6.1	6.4	6.7	6.9	7.2	7.5	15.0
.3	4.6	4.9	5.2	5.5	5.7	6.0	6.3	6.6	6.9	7.2	7.5	7.8	5
5	4.7	5.0	5.3	5.6	5.9	6.2	6.5	6.8	7.1	7.4	7.7	8.0	16.0
.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.7	8.0	8.3	5
.7	5.1	5.3	5.7	6.0	6.3	6.6	6.9	7.2	7.6	7.9	8.2	8.5	17.0
.9	5.2	5.5	5.8	6.2	6.5	6.8	7.1	7.5	7.8	8.1	8.4	8.8	5
.0	5.3	5.7	6.0	6.3	6.7	7.0	7.4	7.7	8.0	8.4	8.7	9.0	18.0
2	5.5	5.8	6.2	6.5	6.8	7.2	7.5	7.9	8.2	8.6	8.9	9.3	5
.3	5.6	6.0	6.3	6.7	7.0	7.4	7.7	8.1	8.5	8.8	9.2	9.5	19.0
.4	5.8	6.1	6.5	6.8	7.2	7.6	7.9	8.3	8.7	9.0	9.4	9.8	5
.6	5.9	6.3	6.7	7.0	7.4	7.8	8.2	8.5	8.9	9.3	9.7	10.0	20.0
.8	6.2	6.6	7.0	7.4	7.8	8.2	8.6	9.0	9.3	9.7	10.1	0.5	1
1	6.5	6.9	7.3	7.7	8.1	8.6	9.0	9.4	9.8	10.2	0.6	1.0	2
.4	6.8	7.2	7.7	8.1	8.5	8.9	9.4	9.8	10.2	0.6	1.1	1.5	3
7	7.1	7.5	8.0	8.4	8.9	9.3	9.8	10.2	10.7	11.1	11.6	12.0	4
0	7.4	7.9	8.3	8.8	9.3	9.7	10.2	0.7	1.1	1.6	2.1	2.5	25.0
2	7.7	8.2	8.7	9.1	9.6	10.1	0.6	1.1	1.6	2.0	2.5	3.0	6
5	8.0	8.5	9.0	9.5	10.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	7
8	8.3	8.8	9.3	9.8	0.4	0.9	1.4	1.9	2.4	3.0	3.5	4.0	8
1	8.6	9.1	9.7	10.2	10.7	11.3	11.8	12.4	12.9	13.4	13.9	14.5	9
3	8.9	9.5	10.0	0.5	1.1	1.7	2.2	2.8	3.3	3.9	4.5	5.0	30.0
6	9.2	9.8	0.3	0.9	1.5	2.1	2.6	3.2	3.8	4.3	4.9	5.5	1
9	9.5	10.1	0.7	1.3	1.9	2.5	3.0	3.6	4.2	4.8	5.4	6.0	2
2	9.8	0.4	1.0	1.6	2.2	2.9	3.5	4.1	4.7	5.3	5.9	6.5	3
5	10.1	10.7	11.3	12.0	12.6	13.3	13.9	14.5	15.1	15.7	16.4	17.0	4
7	0.3	1.0	1.7	2.3	2.9	3.6	4.3	4.9	5.5	6.2	6.9	7.5	35.0
0	0.7	1.3	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	6
3	0.9	1.7	2.3	3.0	3.7	4.4	5.1	5.8	6.5	7.1	7.8	8.5	7
6	1.3	2.0	2.7	3.4	4.1	4.8	5.5	6.2	6.9	7.6	8.3	9.0	8
8	21.6	22.3	13.0	13.7	14.5	15.2	15.9	16.6	17.3	18.1	18.8	19.5	9
2	1.8	2.6	3.3	4.1	4.8	5.6	6.3	7.1	7.8	8.5	9.3	20.0	40.0
6	2.1	2.9	3.7	4.4	5.2	6.0	6.7	7.5	8.1	9.0	9.7	0.5	1
7	2.4	3.2	4.0	4.8	5.5	6.3	7.1	7.9	8.7	9.4	20.2	1.0	2
9	2.7	3.5	4.3	5.1	5.9	6.7	7.5	8.3	9.1	9.0	0.7	1.5	3
2	13.1	13.9	14.7	15.5	16.3	17.1	17.9	18.7	19.6	20.4	21.2	22.0	4
5	3.3	4.2	5.0	5.9	6.7	7.5	8.3	9.2	20.0	0.8	1.7	2.5	45.0
0	3.6	4.5	5.3	6.2	7.1	7.9	8.7	9.6	0.4	1.3	2.2	3.0	6
1	3.9	4.9	5.7	6.5	7.4	8.3	9.1	20.1	0.9	1.7	2.6	3.5	7
4	4.2	5.1	6.0	6.9	7.8	8.7	9.6	0.4	1.3	2.2	3.2	4.0	8
6	14.5	15.4	16.3	17.2	18.1	19.1	20.0	20.8	21.8	22.7	23.6	24.5	9
9	4.8	5.7	6.7	7.6	8.5	9.5	0.4	1.3	2.3	3.2	4.1	5.0	50.0
4	5.4	6.4	7.4	8.3	9.3	20.2	1.2	2.2	3.2	4.1	5.1	6.0	2
0	6.0	7.0	8.0	9.0	20.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	4
6	6.6	7.6	8.7	9.7	0.8	1.8	2.8	3.8	4.8	5.9	6.9	8.0	6
2	27.2	28.3	19.4	20.4	21.5	22.5	23.6	24.7	25.7	26.8	27.8	29.0	8
7	7.8	8.9	20.0	1.1	2.2	3.4	4.4	5.6	6.6	7.7	8.8	30.0	60.0
2	8.4	9.5	0.7	1.8	2.9	4.2	5.2	6.4	7.6	8.7	9.8	1.0	2
8	8.9	20.2	1.4	2.5	3.7	4.9	6.0	7.3	8.4	9.6	30.8	2.0	4
4	9.5	0.8	2.0	3.2	4.4	5.7	6.8	8.1	9.3	30.6	1.7	3.0	6
0	20.1	21.4	22.6	23.0	25.2	26.4	27.7	29.0	30.2	31.5	32.7	34.0	8
4	0.7	2.0	3.4	4.6	5.9	7.2	8.5	9.8	1.1	2.4	3.7	5.0	70.0
7	1.4	2.6	4.0	5.4	6.7	8.0	9.4	30.7	2.0	3.4	4.6	6.0	2
7	1.8	3.3	4.7	6.0	7.4	8.8	30.2	1.5	2.0	4.3	5.7	7.0	4

TABLE 37. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

28	29	30	31	32	33	34	35	36	37	38	39	40	Double Areas
7.5	7.8	8.1	8.4	8.6	8.8	9.1	9.4	9.7	9.9	10.2	10.5	10.7	14.5
7.8	8.0	8.3	8.6	8.9	9.2	9.5	9.7	10.0	10.3	0.6	0.9	1.1	15.0
8.0	8.3	8.6	8.9	9.2	9.5	9.8	10.0	0.3	0.6	0.9	1.2	1.5	5
8.3	8.6	8.9	9.2	9.5	9.8	10.1	0.3	0.7	1.0	1.3	1.6	1.9	16.0
8.5	8.9	9.2	9.5	9.8	10.1	0.4	0.7	1.0	1.3	1.6	1.9	2.2	5
8.8	9.1	9.4	9.8	10.1	10.4	10.7	11.0	11.3	11.7	12.0	12.3	12.6	17.0
9.1	9.4	9.7	10.1	0.4	0.7	1.0	1.3	1.7	2.0	2.3	2.6	3.0	5
9.3	9.7	10.0	0.3	0.7	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	18.0
9.6	9.9	0.3	0.6	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	5
9.8	10.2	0.5	0.9	1.3	1.6	2.0	2.3	2.7	3.0	3.3	3.7	4.1	19.0
10.1	10.5	10.8	11.2	11.6	11.9	12.3	12.6	13.0	13.3	13.7	14.1	14.4	5
0.4	0.7	1.1	1.5	1.9	2.2	2.6	2.9	3.3	3.7	4.1	4.5	4.8	20.0
0.9	1.3	1.7	2.1	2.5	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.5	1
1.1	1.8	2.2	2.6	3.1	3.4	3.9	4.2	4.7	5.1	5.5	5.9	6.3	2
1.9	2.1	2.8	3.2	3.6	4.1	4.5	4.9	5.3	5.7	6.2	6.6	7.1	3
12.5	12.9	13.3	13.8	14.2	14.7	15.1	5.5	16.0	16.4	16.9	17.3	17.8	4
3.0	3.4	3.9	4.4	4.8	5.3	5.7	6.2	6.7	7.1	7.6	8.1	8.5	25.0
3.5	3.9	4.4	4.9	5.4	5.9	6.4	6.8	7.3	7.9	8.3	8.8	9.3	6
4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	20.0	7
4.5	5.1	5.5	6.1	6.6	7.1	7.6	8.1	8.7	9.2	9.7	20.2	0.7	8
15.1	15.5	16.1	16.6	17.2	17.7	18.3	18.8	19.3	19.9	20.4	20.9	21.5	6
5.5	6.1	6.7	7.2	7.8	8.3	8.9	9.4	9.9	20.6	1.2	1.7	2.2	30.0
6.1	6.6	7.2	7.8	8.4	8.9	9.5	20.1	20.7	1.2	1.8	2.4	2.9	1
6.6	7.2	7.7	8.1	8.9	9.6	20.2	0.6	1.3	1.9	2.5	3.2	3.7	2
7.1	7.7	8.3	8.9	9.5	20.2	0.7	1.4	2.0	2.6	3.2	3.8	4.4	3
17.6	18.3	18.9	19.5	20.2	20.8	21.4	22.0	22.7	23.3	23.8	24.6	25.2	4
8.1	8.7	9.5	20.1	0.7	1.3	2.1	2.7	3.3	3.9	4.7	5.3	5.9	35.0
8.7	9.3	20.0	0.7	1.3	1.9	2.7	3.3	3.9	4.6	5.3	6.0	6.7	6
9.2	9.9	0.6	1.2	1.9	2.6	3.2	3.9	4.6	5.3	6.0	6.7	7.4	7
9.7	20.4	1.1	1.8	2.5	3.2	3.9	4.6	5.3	6.0	6.7	7.4	8.1	8
20.2	20.9	21.7	22.3	23.2	23.8	24.6	25.3	25.9	26.7	27.4	28.2	28.9	9
0.7	1.4	2.2	2.9	3.7	4.4	5.2	5.9	6.6	7.4	8.1	8.8	9.6	40.0
1.3	1.9	2.8	3.6	4.3	5.1	5.7	6.5	7.3	8.1	8.8	9.6	30.4	1
1.8	2.6	3.3	4.2	4.8	5.6	6.4	7.2	7.9	8.7	9.6	30.3	1.0	2
2.3	3.1	3.8	4.7	5.4	6.2	7.1	7.8	8.6	9.4	30.2	1.1	1.8	3
22.8	23.6	24.4	25.2	26.1	26.8	27.7	28.4	29.3	30.2	30.9		32.6	4
3.3	4.2	5.0	5.8	6.6	7.5	8.4	9.2	9.9	0.8	1.7	2.5	3.4	45.0
3.8	4.7	5.6	6.3	7.2	8.1	8.9	9.8	30.6	1.5	2.4	3.3	4.2	6
4.3	5.2	6.1	6.9	7.8	8.7	9.6	30.4	1.3	2.2	3.0	3.9	4.8	7
4.8	5.7	6.7	7.6	8.4	9.3	40.2	1.1	2.0	2.8	3.7	4.7	5.5	8
25.4	26.3	27.2	28.2	29.0	20.0	30.8	31.7	32.6	33.6	34.5	35.4	36.3	0
5.9	6.8	7.8	8.7	9.6	30.5	1.4	2.4	3.4	4.2	5.2	6.2	7.1	50.0
6.9	7.8	8.8	9.8	30.8	1.7	2.7	3.7	4.6	5.6	6.6	.5	8.5	2
7.9	8.9	9.9	30.0	2.0	3.0	4.0	5.0	5.9	6.9	8.0	9.0	40.0	4
9.0	30.1	31.1	2.1	3.2	4.2	5.2	6.2	7.3	8.5	9.4	40.4	1.5	6
30.1	31.1	32.2	33.2	34.4	35.4	36.5	37.5	38.6	39.6	40.8	41.8	42.9	8
1.1	2.2	3.3	4.4	5.6	6.6	7.7	8.0	40.0	41.1	2.2	3.4	4.4	60.0
2.2	3.2	4.4	5.6	6.7	7.8	9.0	40.1	1.3	2.4	3.6	4.8	5.9	2
3.2	4.4	5.5	6.6	7.8	9.1	40.2	1.4	2.6	3.8	5.0	6.2	7.4	4
4.2	5.4	6.6	7.8	9.1	40.2	1.5	2.7	3.9	5.2	6.4	7.6	8.8	6
35.2	36.4	37.7	39.0	40.2	41.5	42.8	44.0	45.2	46.5	47.8	49.0	50.4	8
6.3	7.6	8.8	40.1	1.4	2.8	4.0	5.4	6.6	8.0	9.2	50.5	1.8	70.0
7.3	8.7	9.0	1.3	2.6	4.0	5.3	6.6	8.0	9.2	50.6	2.0	3.3	2
8.4	9.7	41.1	2.5	3.8	5.2	6.6	7.9	9.4	50.7	2.2	3.4	4.8	4

TABLE 37.— *continued*

ANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

	42	43	44	45	46	47	48	49	50	75	100		D'uble Areas
0	11.3	11.5	11.8	12.1	12.3	12.6	12.9	13.1	13.4	20.2	26.8	—	14.5
4	1.7	1.9	2.2	2.5	2.8	3.0	3.3	3.6	3.9	0.8	7.8	—	15.0
9	2.1	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.4	1.5	8.7	—	5
1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5	4.8	2.2	9.6	—	16.0
5	2.8	3.1	3.4	3.7	4.1	4.2	4.7	4.9	5.3	2.8	30.5	—	5
9	13.2	13.5	13.8	14.2	14.5	14.8	15.1	15.4	15.7	23.6	31.4	—	17.0
5	3.6	3.9	4.3	4.6	4.9	5.2	5.5	5.9	6.2	4.3	2.4	—	5
7	4.0	4.3	4.7	5.0	5.3	5.7	6.0	6.3	6.7	4.9	3.3	—	18.0
1	4.4	4.7	5.1	5.4	5.7	6.1	6.4	6.7	7.1	5.7	4.2	—	5
4	4.7	5.1	5.5	5.8	6.1	6.5	6.9	7.2	7.6	6.4	5.2	—	19.0
8	15.1	15.5	15.9	16.3	16.6	16.9	17.3	17.7	18.1	27.1	36.1	—	5
2	5.5	5.9	6.3	6.7	7.1	7.4	7.7	8.1	8.5	7.8	7.0	—	20.0
9	6.3	6.7	7.1	7.5	7.9	8.3	8.7	9.0	9.5	9.2	8.8	—	1
7	7.1	7.5	7.9	8.3	8.7	9.1	9.5	9.9	20.4	30.6	40.7	—	2
5	7.9	8.3	8.7	9.1	9.6	20.0	20.4	20.8	1.3	1.9	2.6	—	3
4	18.6	19.1	19.5	20.0	20.4	20.8	21.3	21.8	22.2	33.3	44.4	—	4
0	9.5	9.9	20.3	0.8	1.3	1.7	2.2	2.7	3.2	4.7	6.2	—	25.0
7	20.2	20.7	1.2	1.7	2.2	2.6	3.1	3.6	4.1	6.1	8.2	—	6
5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	7.5	50.0	—	7
3	1.8	2.3	2.8	3.3	3.8	4.4	4.8	5.4	5.9	8.8	1.8	—	8
0	22.6	23.1	23.7	24.2	24.7	25.2	25.8	26.3	26.8	40.3	53.7	—	9
8	3.3	3.8	4.4	5.0	5.5	6.1	6.7	7.2	7.8	1.6	5.5		30.0
5	4.1	4.7	5.2	5.8	6.4	6.9	7.6	8.1	8.7	3.2	7.3	—	1
3	4.8	5.4	6.1	6.6	7.2	7.8	8.4	9.1	9.6	4.4	9.2	—	2
0	5.7	6.3	6.8	7.5	8.1	8.7	9.3	9.9	30.6	5.8	61.0	—	3
7	26.4	27.0	27.7	28.3	28.9	29.6	30.2	30.8	31.4	47.2	62.9	—	4
6	7.2	7.8	8.5	9.2	9.8	30.4	1.1	1.7	2.4	8.6	4.8	—	35.0
5	8.0	8.6	9.3	30.0	30.6	1.3	2.0	2.6	3.3	9.9	6.7	—	6
1	8.8	9.4	30.1	0.8	1.5	2.2	2.8	3.6	4.3	51.4	8.5	—	7
8	9.6	30.2	1.0	1.6	2.4	3.1	3.7	4.5	5.2	2.8	70.4	—	8
6	30.4	31.0	31.7	32.5	33.2	33.8	34.6	35.4	36.1	54.1	72.1	—	9
4	1.2	1.8	2.6	3.3	4.0	4.8	5.6	6.3	7.0	5.5	4.0	—	40.0
2	1.8	2.6	3.4	4.2	4.8	5.6	6.4	7.2	8.0	6.9	5.8	—	1
8	2.7	3.4	4.2	5.0	5.8	6.6	7.3	8.2	8.9	8.3	7.8	—	2
6	3.4	4.2	5.0	5.8	6.6	7.4	8.2	9.0	9.8	9.6	9.6	—	3
4	34.2	35.0	35.8	36.7	37.4	38.3	39.2	39.9	40.8	61.1	81.5	—	4
2	4.9	5.8	6.7	7.4	8.3	9.2	9.9	40.7	1.6	2.4	3.4	—	45.0
8	5.7	6.6	7.4	8.3	9.1	40.0	40.9	1.7	2.6	3.8	5.2	—	6
7	6.6	7.4	8.3	9.2	40.0	0.9	1.8	2.7	3.5	5.3	7.0	—	7
4	7.3	8.2	9.2	40.0	0.8	1.7	2.6	3.5	4.4	6.7	8.9	—	8
2	38.1	39.0	39.9	40.8	41.7	42.6	43.5	44.4	45.3	68.1	90.6	—	9
9	8.8	9.8	40.7	1.6	2.6	3.5	4.4	5.3	6.4	9.3	2.6	—	50.0
3	40.4	41.3	2.3	3.3	4.2	5.2	6.2	7.2	8.2	72.2	6.3	—	2
0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	50.0	5.0	100.0	—	4
5	3.5	4.6	5.6	6.6	7.7	8.7	9.8	50.8	1.8	7.8	03.6	—	6
1	45.2	46.2	47.3	48.4	49.4	50.5	51.5	52.6	53.7	80.5	107.3	—	8
6	6.7	7.8	8.9	50.0	51.1	2.2	3.3	4.4	5.5	3.4	11.0	—	60.0
1	8.2	9.4	50.5	1.6	2.8	4.0	5.1	6.2	7.4	6.1	14.8		2
6	9.7	50.9	2.1	3.3	4.5	5.7	6.9	8.1	9.3	8.9	18.6	—	4
2	51.3	2.5	3.7	5.0	6.2	7.4	8.6	9.9	61.1	91.7	22.1	—	6
6	52.8	54.1	55.4	56.7	58.0	59.2	60.4	61.7	63.0	94.5	125.9	—	8
1	4.4	5.7	7.0	8.3	9.6	60.9	2.2	3.5	4.8	7.1	29.5	—	70.0
7	6.0	7.3	8.6	60.0	61.3	2.6	4.0	5.4	6.6	100.0	33.2	—	2
1	7.6	8.9	60.3	1.7	3.1	4.4	5.8	7.2	8.6	02.9	37.2	—	4

TABLE 37. — *continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

2	3	4	5	6	7	8	9	10	11	12	13	14	D'ble Area
2.8	4.2	5.6	7.0	8.5	9.9	11.3	12.7	14.1	15.5	16.9	18.3	19.7	76.0
2.9	4.3	5.8	7.2	8.7	10.1	1.6	3.0	4.5	5.9	7.4	8.8	20.2	8
3.0	4.4	5.9	7.4	8.9	0.4	1.9	3.3	4.9	6.3	7.8	9.3	0.8	80.0
3.0	4.6	6.1	7.6	9.1	0.7	2.2	3.7	5.2	6.7	8.2	9.8	1.3	2
3.1	4.7	6.2	7.8	9.3	0.9	2.5	4.0	5.6	7.1	8.7	20.2	1.7	4
3.2	4.8	6.4	8.0	9.6	11.2	12.7	14.3	15.9	17.5	19.1	20.7	22.3	6
3.3	4.9	6.5	8.1	9.8	1.4	3.1	4.7	6.3	7.9	9.5	1.2	2.8	8
3.3	5.0	6.7	8.3	10.0	1.7	3.3	5.0	6.7	8.3	20.0	1.7	3.4	90.0
3.4	5.1	6.8	8.5	0.2	1.9	3.6	5.4	7.1	8.7	0.4	2.1	3.8	2
3.5	5.2	7.0	8.7	0.5	2.2	3.9	5.7	7.4	9.2	0.8	2.6	4.4	4
3.5	5.3	7.1	8.9	10.7	12.5	14.2	16.0	17.8	19.5	21.3	23.1	24.9	6
3.6	5.4	7.3	9.1	0.9	2.7	4.5	6.4	8.2	9.9	1.8	3.6	5.4	8
3.7	5.6	7.4	9.3	1.1	3.0	4.8	6.7	8.5	20.4	2.2	4.1	6.0	100.0
3.9	5.8	7.8	9.7	1.7	3.6	5.5	7.5	9.5	1.4	3.3	5.3	7.2	05
4.1	6.1	8.1	10.2	2.2	4.3	6.3	8.4	20.4	2.4	4.4	6.5	8.6	10
4.3	6.4	8.5	10.7	12.8	14.9	17.0	19.1	21.3	23.4	25.5	27.7	29.8	15
4.4	6.7	8.9	1.1	3.3	5.5	7.8	20.0	2.3	4.4	6.6	8.8	31.2	20
4.6	6.9	9.2	1.6	3.9	6.2	8.5	0.8	3.2	5.4	7.7	30.2	2.4	125.0
4.8	7.2	9.6	2.1	4.5	6.9	9.3	1.7	4.1	6.5	8.8	1.4	3.7	30
5.0	7.5	10.0	2.5	5.0	7.5	20.0	2.5	5.0	7.5	9.9	2.5	5.0	35
5.2	7.8	10.4	12.9	15.5	18.2	20.8	23.4	25.9	28.5	31.1	33.7	36.4	40
5.4	8.0	0.7	3.4	6.1	8.8	1.5	4.2	6.8	9.5	2.2	4.8	7.6	45
5.6	8.3	1.1	3.9	6.7	9.5	2.3	5.0	7.8	30.6	3.4	6.1	8.8	150.0
5.7	8.6	1.5	4.3	7.2	20.1	2.9	5.8	8.7	1.6	4.5	7.3	40.2	55
5.9	8.9	1.9	4.8	7.8	0.7	3.7	6.7	9.6	2.6	5.6	8.5	1.5	60
6.1	9.2	12.2	15.3	18.3	21.4	24.4	27.5	30.6	33.6	36.6	39.7	42.8	65
6.3	9.5	2.6	5.8	8.9	2.1	5.2	8.3	1.5	4.6	7.7	40.9	4.1	70
6.5	9.7	3.0	6.2	9.4	2.7	5.9	9.2	2.4	5.6	8.9	2.1	5.5	175.0
6.7	10.0	3.3	6.7	20.0	3.3	6.7	30.0	3.3	6.7	40.0	3.3	6.6	80
6.9	0.3	3.7	7.1	0.6	4.0	7.4	0.9	4.2	7.7	1.2	4.5	8.0	85
7.0	10.5	14.1	17.6	21.2	24.6	28.2	31.7	35.2	38.7	42.2	45.7	49.3	90
7.2	0.8	4.5	8.1	1.6	5.2	8.8	2.5	6.2	9.7	3.3	7.0	50.5	95
7.4	1.1	4.9	8.5	2.2	5.9	9.6	3.4	7.1	40.8	4.4	8.2	1.9	200.0
7.8	1.7	5.6	9.5	3.4	7.2	31.1	5.0	8.9	2.8	6.7	50.5	4.4	10
8.1	2.2	6.3	20.4	4.4	8.5	2.6	6.7	40.8	4.8	8.8	3.0	7.1	20
8.5	12.7	17.1	21.3	25.6	29.8	34.1	38.4	42.6	46.8	51.1	55.4	59.6	30
8.9	3.3	7.7	2.2	6.6	31.1	5.6	40.0	4.4	8.8	3.3	7.8	62.2	40
9.2	3.9	8.5	3.1	7.8	2.4	7.0	1.7	6.3	50.9	5.6	60.2	4.8	250.0
9.6	4.5	9.3	4.1	8.9	3.7	8.5	3.4	8.1	2.9	7.8	2.7	7.4	60
10.0	5.0	20.0	5.0	30.0	5.0	9.9	5.0	50.0	5.0	60.0	4.9	70.0	70
10.4	15.6	20.7	25.9	31.1	36.3	41.4	46.7	51.9	57.0	62.2	67.4	72.5	80
0.8	6.1	1.4	6.8	2.2	7.6	3.0	8.3	3.8	9.1	4.4	9.8	5.2	90
1.1	6.7	2.2	7.8	3.3	8.8	4.4	50.0	5.6	61.1	6.8	72.2	7.9	300.0
1.5	7.2	2.9	8.6	4.4	40.2	5.9	1.8	7.4	3.1	8.8	4.5	80.4	10
1.9	7.8	3.6	9.6	5.5	1.1	7.4	3.3	9.1	5.2	71.1	7.0	3.0	20
12.2	18.3	24.4	30.6	36.6	42.8	48.9	55.0	61.2	67.2	73.3	79.4	85.6	30
2.6	8.9	5.2	1.1	7.7	4.1	50.5	6.7	2.0	9.2	5.5	81.8	8.1	40
3.0	9.5	5.0	2.4	8.9	5.4	1.8	8.3	4.8	71.3	7.8	4.2	90.8	350.0
3.3	20.0	6.6	3.3	0.0	6.6	3.4	60.0	6.8	3.3	80.0	6.8	3.3	60
3.7	0.6	7.4	4.3	41.1	7.9	4.8	1.6	8.5	5.3	2.1	9.0	6.0	70
14.1	21.2	28.2	35.2	42.2	49.2	56.3	63.3	70.3	77.4	84.5	91.5	98.5	80
4.4	1.6	8.8	6.1	3.3	50.6	7.8	5.0	2.2	9.4	6.6	3.9	101.1	90
4.8	2.2	9.6	7.1	4.4	1.8	9.2	6.7	4.1	81.5	8.9	6.3	3.6	400.0

TABLE 37.— *continued*

ε HORIZONTAL   SUM OF AREAS VERTICAL   QUANTITIES IN CUBIC YARDS

6	17	18	19	20	21	22	23	24	25	26	27	D'uble Areas
2.5	23.9	25.3	26.7	28.2	29.6	31.0	32.4	33.8	35.2	36.6	38.0	76.0
3.1	4.6	6.0	7.4	8.9	30.3	1.8	3.2	4.7	6.0	7.5	9.0	8
3.7	5.2	6.7	8.2	9.6	1.1	2.6	4.1	5.6	7.0	8.5	40.0	80.0
4.3	5.8	7.3	8.9	30.4	1.8	3.4	4.9	6.4	7.9	9.4	1.0	2
4.8	6.4	8.0	9.6	1.2	2.7	4.2	5.8	7.3	8.8	40.4	2.0	4
5.5	27.1	28.6	30.2	31.8	33.4	35.0	36.6	38.2	39.8	41.4	43.0	6
6.1	7.7	9.3	0.9	2.6	4.2	5.8	7.5	9.1	40.7	2.3	4.0	8
6.7	8.3	30.0	1.7	3.4	5.0	6.6	8.4	40.0	1.6	3.3	5.0	90.0
7.2	8.9	0.6	2.3	4.1	5.8	7.5	9.2	0.9	2.6	4.3	6.0	2
7.8	9.6	1.3	3.1	4.8	6.5	8.2	40.0	1.8	3.5	5.2	7.0	4
8.4	30.2	32.0	33.7	35.5	37.3	39.0	40.8	42.7	44.4	46.2	48.0	6
9.0	0.8	2.6	4.4	6.3	8.0	9.8	1.7	3.6	5.4	7.1	9.0	8
9.6	1.5	3.3	5.2	7.0	8.9	40.8	2.6	4.4	6.3	8.1	50.0	100.0
1.2	3.0	5.0	7.0	8.9	40.8	2.7	4.7	6.6	8.5	50.5	2.5	05
2.6	4.0	6.6	8.7	40.7	2.7	4.7	6.8	8.8	50.9	2.9	5.0	10
4.1	36.2	38.4	40.5	42.6	44.7	46.8	48.9	51.0	53.2	55.4	57.5	15
5.5	7.7	9.9	2.2	4.4	6.6	8.8	51.0	3.3	5.5	7.8	60.0	20
7.0	9.3	41.6	3.9	6.3	8.6	50.9	3.2	5.5	7.8	60.1	2.5	125.0
8.5	40.9	3.3	5.7	8.2	50.5	2.9	5.3	7.8	60.2	2.6	5.0	30
0.0	2.5	5.0	7.5	50.0	2.5	5.0	7.5	60.0	2.5	5.0	7.5	35
1.4	44.0	46.6	49.2	51.8	54.4	57.0	59.6	62.2	64.8	67.4	70.0	40
2.9	5.6	8.3	51.0	3.7	6.3	9.0	61.7	4.4	7.0	9.8	2.5	45
4.4	7.2	9.9	2.8	5.7	8.2	61.1	3.9	6.6	9.3	72.2	5.0	150.0
5.9	8.7	51.6	4.5	7.6	60.3	3.1	6.0	8.8	71.8	4.6	7.5	55
7.3	50.4	3.3	6.2	9.3	2.1	5.1	8.1	71.1	4.0	7.0	80.0	60
8.8	52	55.0	58.0	61.0	64.2	67.1	70.3	73.4	76.2	79.3	82.5	65
0.5	3.5	6.6	0.8	3.0	6.0	9.2	2.3	5.5	8.7	81.8	5.0	70
1.8	5.0	8.3	61.5	4.8	8.0	71.2	4.6	7.7	81.0	4.3	7.5	175.0
3.3	6.6	60.0	3.3	6.8	9.9	3.2	6.7	80.0	3.7	6.7	90.0	80
4.8	8.1	1.6	5.0	8.5	71.9	5.3	8.8	2.2	5.6	9.0	2.5	85
6.2	59.8	63.3	66.8	70.4	73.8	77.3	80.9	84.3	87.9	91.7	95.0	90
7.8	61.3	5.0	8.7	2.1	5.7	9.4	3.0	6.7	90.2	3.9	7.5	95
9.2	2.9	6.7	70.3	4.0	7.7	81.4	5.1	8.9	2.8	6.4	100.0	200.0
2.1	6.0	70.0	3.8	7.8	81.7	5.5	9.4	93.4	7.2	101.2	05.0	10
5.1	9.3	3.2	7.4	81.5	5.5	9.5	93.7	7.8	101.9	06.0	10.0	20
8.0	72.4	76.6	80.9	85.2	89.4	93.7	98.0	102.2	106.5	110.8	115.0	30
1.0	5.5	9.9	4.3	8.9	93.2	7.8	102.2	106.8	11.1	15.5	20.0	40
4.0	8.6	83.2	7.9	92.5	7.1	101.9	06.5	11.1	15.9	20.5	25.0	250.0
7.0	81.8	6.5	91.4	6.5	101.2	06.0	10.7	15.5	20.4	25.3	30.0	60
0.0	5.0	90.0	4.9	100.0	05.0	10.0	15.1	20.0	25.0	30.0	35.0	70
2.9	88.1	93.2	98.4	103.8	108.9	114.1	119.2	124.5	129.5	134.8	140.0	80
5.9	91.2	6.5	102.1	07.4	12.9	18.1	23.5	28.9	34.3	39.8	45.0	90
8.9	4.4	100.0	05.7	11.1	16.8	22.2	29.7	33.3	38.9	44.5	50.0	300.0
1.8	7.5	03.3	09.2	14.8	20.6	26.3	32.1	37.9	43.5	49.3	55.0	10
4.7	100.9	06.8	12.7	18.6	24.3	30.3	36.2	42.2	48.1	54.1	60.0	20
7.7	103.9	110.0	116.1	122.2	128.3	134.5	140.6	146.8	152.8	158.9	165.0	30
0.7	07.1	13.2	19.6	26.0	32.2	38.5	44.9	51.2	57.2	63.8	70.0	40
3.8	10.2	16.7	23.2	29.7	36.2	42.5	49.1	55.5	62.0	68.5	75.0	350.0
6.6	13.4	20.0	26.8	33.3	40.0	46.6	53.2	60.0	66.8	73.4	80.0	60
9.6	16.4	23.2	30.2	37.0	43.8	50.7	57.5	64.5	71.2	78.1	85.0	70
2.5	119.6	126.8	133.8	140.8	147.8	154.8	161.8	168.9	175.9	183.0	190.0	80
5.9	22.9	30.0	37.2	44.3	51.7	58.0	66.1	73.4	80.5	87.8	95.0	90
8.5	25.9	33.3	40.7	48.1	55.6	63.0	70.4	77.8	85.2	92.6	200.0	400.0

TABLE 37. — *Continued*

DISTANCE HORIZONTAL SUM OF AREAS VERTICAL QUANTITIES IN CUBIC YARDS

28	29	30	31	32	33	34	35	36	37	38	39	40	D'ble Areas
39.4	40.8	42.2	43.6	45.1	46.5	47.9	49.3	50.7	52.1	53.5	54.9	56.3	76.0
40.4	1.8	3.3	4.8	6.2	7.7	9.1	50.5	2.0	3.5	4.9	6.4	7.8	8
1.5	3.0	4.4	5.9	7.4	8.8	50.3	1.8	3.3	4.8	6.3	7.8	9.2	80.0
2.5	4.1	5.6	7.1	8.6	50.1	1.7	3.2	4.7	6.2	7.7	9.2	60.8	2
3.6	5.2	6.7	8.2	9.8	1.3	2.9	4.5	6.0	7.5	9.1	60.7	2.3	4
44.6	46.2	47.8	49.3	51.0	52.5	54.2	55.7	57.3	58.9	60.5	62.1	63.7	6
5.6	7.2	8.8	50.5	2.1	3.7	5.4	7.0	8.7	60.3	1.9	3.5	5.2	8
6.7	8.3	50.0	1.7	3.3	5.0	6.7	8.3	60.0	1.6	3.3	5.0	6.6	90.0
7.7	9.4	1.1	2.8	4.5	6.2	7.9	9.6	1.3	3.0	4.7	6.4	8.2	2
8.8	50.5	2.2	4.0	5.7	7.5	9.2	61.0	2.7	4.4	6.2	7.9	9.7	4
49.8	51.5	53.3	55.1	56.9	58.7	60.4	62.2	64.0	65.8	67.6	69.4	71.2	6
50.8	2.6	4.4	6.3	8.1	9.9	1.7	3.5	5.3	7.1	8.9	70.8	2.6	8
1.8	3.7	5.5	7.4	9.3	61.1	3.0	4.8	6.6	8.5	70.3	2.2	4.0	100.0
4.4	6.4	8.3	60.3	62.2	4.2	6.1	8.1	70.0	72.0	3.9	5.8	7.8	05
7.0	9.1	61.1	3.2	5.2	7.2	9.3	71.3	3.3	5.4	7.4	9.5	81.5	10
59.7	61.8	64.0	66.0	68.1	70.4	72.5	74.5	76.7	78.8	81.0	83.1	85.2	15
62.3	4.5	6.7	8.9	71.1	3.4	5.5	7.8	80.0	82.2	4.5	6.7	9.0	20
4.8	7.2	9.5	71.8	4.1	6.5	8.8	81.0	3.4	5.6	8.0	90.3	92.7	125.0
7.3	9.8	72.2	4.5	7.0	9.4	81.8	4.2	6.6	9.0	91.4	3.9	6.3	30
70.0	72.5	5.0	7.5	80.0	82.5	5.0	7.5	90.0	92.5	5.0	7.5	100.0	35
72.6	75.2	77.8	80.4	83.0	85.6	88.1	90.7	93.4	96.0	98.5	101.1	103.7	40
5.2	7.9	80.5	3.2	5.9	8.6	91.3	4.0	6.7	9.4	102.0	04.8	07.5	45
7.8	80.6	3.3	6.1	8.9	91.7	4.4	7.2	100.0	102.8	05.6	08.3	11.1	150.0
80.4	3.2	6.2	9.0	91.9	4.7	7.6	100.5	03.3	06.2	09.1	12.0	14.8	55
2.9	5.9	8.8	91.8	4.7	7.7	100.8	03.8	06.7	09.7	12.6	15.6	18.5	60
85.5	88.5	91.6	94.7	97.7	100.9	103.9	107.0	110.0	113.1	116.1	119.2	122.2	65
8.1	91.3	4.4	7.6	100.8	03.9	07.1	10.2	13.3	16.6	19.7	22.8	26.0	70
90.8	4.0	7.3	100.5	03.8	07.0	10.2	13.4	16.7	20.0	23.2	26.4	29.6	175.0
3.4	6.6	100.0	03.3	06.8	10.0	13.4	16.8	20.0	23.3	26.7	30.1	33.4	80
6.0	9.4	02.8	06.2	09.6	13.1	16.5	19.9	23.4	26.8	30.2	33.7	37.1	85
98.6	102.1	105.6	109.1	112.6	116.1	119.7	123.2	126.7	130.2	133.8	137.3	140.8	90
101.2	04.8	08.4	12.0	15.6	19.2	22.9	26.4	30.0	33.6	37.2	40.9	44.5	95
03.7	07.4	11.1	14.9	18.6	22.2	26.0	29.6	33.3	37.0	40.6	44.4	48.1	200.0
08.8	12.8	16.6	20.6	24.4	28.4	32.2	36.2	40.0	44.0	47.8	51.6	55.6	10
14.0	18.2	22.2	26.4	30.4	34.4	38.6	42.6	46.8	50.8	54.8	59.0	63.0	20
119.4	123.6	127.8	132.0	136.2	140.6	145.0	149.0	153.4	157.6	162.0	166.2	170.4	30
24.6	29.0	33.4	37.8	42.2	46.8	51.0	55.6	60.0	64.4	69.0	73.4	78.0	40
29.6	34.4	39.0	43.6	48.2	53.0	57.6	62.0	66.8	71.4	76.0	80.6	85.2	250.0
34.6	39.4	44.2	49.0	54.0	58.8	63.6	68.4	73.2	78.0	82.8	87.8	92.6	60
40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	200.0	70
145.2	150.4	155.6	161.0	166.0	171.2	176.2	181.4	186.8	192.0	197.0	202.2	207.4	80
50.4	55.8	61.0	66.4	71.8	77.2	82.6	88.0	93.3	98.8	204.0	09.6	14.8	90
55.6	61.2	66.8	72.2	77.8	83.4	89.0	94.4	200.0	205.6	11.2	16.6	22.2	300.0
60.8	66.4	72.2	78.0	83.8	89.4	95.2	201.0	06.8	12.4	18.2	24.0	29.6	10
65.8	71.8	77.6	83.6	89.4	95.4	201.6	07.6	13.6	19.4	25.2	31.2	37.0	20
171.0	177.0	183.2	189.4	195.4	201.8	207.8	214.0	220.0	226.2	232.2	238.4	244.4	30
76.2	82.6	88.8	95.2	201.6	07.8	14.2	20.4	26.7	33.2	39.4	45.6	52.0	40
81.6	88.0	94.6	201.0	07.6	14.0	20.4	26.8	33.4	40.0	46.4	52.8	59.2	350.0
86.8	93.2	200.0	06.6	13.4	20.0	26.8	33.4	40.0	46.6	53.4	60.0	66.6	60
92.0	98.8	05.6	12.4	19.2	26.2	33.0	39.8	46.8	53.6	60.4	67.4	74.2	70
197.2	*204.2*	*211.2*	*218.4*	*225.6*	*232.2*	*239.4*	*246.4*	*253.4*	*260.4*	*267.6*	*274.6*	*281.6*	80
202.4	*09.6*	*16.8*	*24.0*	*31.2*	*38.4*	*45.6*	*52.8*	*60.0*	*67.2*	*74.4*	*81.6*	*88.8*	90
07.4	*14.8*	*22.2*	*29.6*	*37.0*	*44.4*	*51.8*	*59.2*	*66.6*	*74.0*	*81.4*	[illegible]	[illegible]	400.0

TABLE 37. — *Continued*

…TANCE HORIZONTAL   SUM OF AREAS VERTICAL   QUANTITIES IN CUBIC YARDS

1	42	43	44	45	46	47	48	49	50	75	100		D'ubl Areas
7.7	59.1	60.6	61.9	63.4	64.8	66.2	67.6	69.0	70.4	105.7	140.7	—	76.0
9.2	60.7	2 1	3.6	5.0	6.4	7.8	9.3	70.7	2 3	08.4	44.4	—	8.0
0.8	2.2	3.7	5.2	6.7	8.2	9.7	71.2	2.6	4.1	11 2	48.1	—	80.0
2.2	3.8	5 3	6.8	8.3	9.8	71.4	2.9	4.4	5.9	14.0	51 8	—	2
3.8	5.4	6.9	8.4	70.0	71.6	3 2	4.7	6.2	7 8	16.8	55.5	—	4
5 3	66.8	68.4	70.1	71 7	73 3	74.8	76.4	78.0	79.6	119.5	159.2	—	6
6.8	8.4	70.1	1 7	3.4	5.0	6.6	8.3	9.8	81.5	22.3	63.0	—	8
8.4	70.0	1 7	3.3	5.0	6 7	8.4	80.0	81 7	3.4	25 1	66.7	—	90.0
9.8	1.6	3.3	4.9	6.7	8.4	80.1	1 8	3 5	5 2	27.9	70.6	—	2
1.4	3.2	4.8	6.6	8.4	80.1	1.9	3.6	5 3	7 1	30.7	74 1	—	4
2.8	74.7	76.4	78.2	80.0	81.8	83.6	85.3	87 1	88.9	133.4	177 7	—	6
4.4	6.3	8.1	9.9	1 7	3.5	5.3	7 1	8.9	90.8	36 1	81 6	—	8
5.9	7 7	9.7	81.4	3.3	5 2	7.0	8.8	90.7	2 6	38 9	85 1	—	100.0
7.8	81.7	83.6	5.6	7 5	9.4	91.4	93.4	95 3	7 2	45 9	94 4	—	05
9.5	5.6	7.6	9.6	91 7	93 7	5.7	7.8	9.8	101.9	52.8	203 7	—	10
1.3	89.4	91.6	93.7	95.8	97.9	100.1	102 2	104.4	106 5	159.8	212.9	—	15
1 1	93.4	5.6	7.8	100.0	102 2	04 5	06.7	08.9	11 1	66 7	22 2	—	20
4.9	7.3	9.7	101.9	04 2	06.5	08.9	11 2	13 5	15 6	73 7	31 4	—	125.0
8.8	101.2	103.6	05.9	08.4	10.7	13 1	15.5	17.9	20.2	80.5	40.7	—	30
1.5	05.0	07.5	10.0	12.5	15.0	17 5	20.0	22 5	25.0	87 5	50.0	—	35
6.3	108.9	111.5	114.2	116.7	119.3	121.9	124.4	127.1	129.8	194 5	259.2	—	40
0.1	12.9	15.5	18.2	20.8	23.6	26.2	28.9	31 7	34 3	201 5	68.5	—	45
3.9	16.7	19.5	22.3	25.0	27.8	30.6	33.4	36.2	38 9	08.5	77 7	—	150.0
7.8	20.6	23.5	26.3	29.2	32 1	34 9	37.8	40.8	43 6	15.4	87.0	—	55
1.5	24.5	27.4	30.4	33.4	36.4	39 4	42 3	45 2	48.2	22.4	96 3	—	60
5.3	128 4	131 5	134.4	137 6	140.6	143 8	146.8	149.8	152 8	229.3	305.5	—	65
9.1	32 2	35 4	38.5	41 7	44.9	48.0	51 2	54 3	57.4	36 1	14 8	—	70
2.9	36.1	39.4	42.5	45.8	49.0	52 2	55 5	58.8	62.0	43.0	24.0	—	175.0
6.8	40.0	43.4	46.8	50.0	53 4	56.8	60.0	63.4	66.8	50.0	33.3	—	80
0.5	43.9	47.4	50.8	54.2	57 7	61 0	64 5	67 9	71.4	56 9	42.6	—	85
4.4	147.8	151.4	154.9	158.4	161.9	165.4	168.9	172.4	176.0	263.9	351.8	—	90
8.1	51.8	55.3	58.9	62 5	66.2	69.8	73.4	77.0	80.5	70.8	61.1	—	95
1.8	55.6	59.3	63 0	66.8	70.4	74 1	77.8	81 4	85 2	77.7	70.3	—	200.0
9.5	63.4	67 3	71 1	75.0	78.9	82.8	86 7	90.5	94 5	91.6	88.9	—	10
7.0	71 2	75.2	79.3	83.4	87.5	91 5	95 6	99.7	203 7	305 5	407.4	—	20
4.7	178.9	183 1	187.5	191.8	196.0	200.1	204 4	208 8	213.0	319.4	425 9		30
2	86.8	91.1	95.5	200.0	204.5	08.8	13 3	17.8	22 2	33 3	44.4	—	40
9.8	94 5	99.0	203.7	08.3	13.0	17 5	22 2	26.8	31 5	47 1	62 9	—	250.0
7.4	202.3	207.0	11.9	16.6	21 6	26 3	31 1	36 0	40 8	61.0	81 5	—	60
5.0	10.0	15.0	20.0	25.0	230.0	35 0	40.0	45.0	50.0	75.0	500.0	—	70
2.7	217.8	223.0	228.2	233.3	238.6	243 7	248.9	254 1	259.2	388 7	518.5	—	80
0.2	25.6	30.9	36.3	41 7	47 1	52.4	57.8	63 2	68.5	402 7	37.0	—	90
7.8	33 4	38.9	44 5	50.0	55.6	61 1	66.7	72 3	77 8	16.5	55 5	—	300.0
5.4	41 2	46.9	52 6	58.3	64.2	69.8	75 6	81 3	87.0	30.4	74.0	—	10
3.0	49.0	54.8	60.8	66 7	72 7	78.5	84.4	90.4	96.3	44.3	92.6	—	20
0.6	256 7	262.8	268.9	275.0	281 1	287 2	293 3	299.5	305.5	458 2	611 0	—	30
8.1	64.5	70.7	77 1	83 3	89 7	95 9	302 2	308 5	14 8	72 1	29.6	—	40
5.7	72.3	78 7	85 2	91 7	98.2	304.6	11 1	17 6	24 1	85.9	48.1	—	350.0
3.3	80.1	86.7	93.4	300.0	306.8	13.3	20.0	26.7	33.0	99.8	66.6	—	60
0.9	87 9	94.6	301 5	08.3	15 3	22.0	28 9	35 8	42 6	513.7	85 2	—	70
8.5	295.6	302.6	309.7	316.7	323.8	330.7	337.8	344.8	351 8	527 6	703.6	—	80
6.1	303.4	10.5	17.8	25.0	32 3	339 4	46 7	53 9	61 1	41 5	22 2	—	90
3.7	11 1	18.5	25.9	33.3	40.7	48.1	55.5	62.9	70 3	55.5	40 6	—	400.0

Overhaul.

If dirt must be hauled more than a stated distance (free haul) to place it in fill, the additional distance is called overhaul and is paid for at an agreed rate; the amount of overhaul is estimated as the (number of cubic yards that have to be overhauled) × (the distance beyond the free haul expressed in stations, that is units of 100 ft.). That is, if 20 cu. yds. had to be hauled 3,000 ft. when the free haul was 2,000 ft., the overhaul would be expressed as 10 stations × 20 yds.

Overhaul is to be avoided if possible, as it is a source of dispute between Contractor and Engineer. Where necessary it can often be computed from an inspection of the earthworks computation sheets. If the cut from which the dirt is drawn is short and well defined and the fill to which it is taken is likewise well defined, the position of the centers of gravity of both cut and fill can be located sufficiently close by inspection; however, if two or three cuts are hauled to one fill or one cut to more than one fill, the amount and length of overhaul can only be determined with accuracy by means of a mass diagram.

In Fig. 64 an earthwork chart is given which was prepared for the Batavia-Buffalo road, State Route 6, Sections 10 and 11. This chart gives amount, location, direction, and length of haul for excavation at a glance, and as an example of overhaul has been illustrated on the diagram this will indicate the method.

Explanation of Fig. 64, page 217.

1. The horizontal scale represents stations along road: in this case 5 stations or 500 ft. to the inch.

2. The vertical scale represents the algebraic sum of the excavation and embankment on whose vertical the amount is plotted. In this case 200 cu. yds. to the inch.

3. Reading from left to right, all ascending lines indicate amount and location of excavation; all descending lines indicate amount and location of embankment.

4. All embankment quantities in each balancing section were multiplied by the factor written above that section as "Balance Used."

5. The excavation and embankment quantities at each station were added together algebraically, after the embankment quantities had been increased as specified; the algebraic sum so obtained was then added algebraically to the sum similarly obtained from previous sections.

6. This diagram indicates the amount of material that should be excavated or deposited at each station.

7. The diagram indicates the direction of haul.

8. To compute overhaul consider the section *A B C D E A*. Suppose free haul is to be 500 ft. Find where a line 500 ft. long *will fit the section. B D* is such a line. The material above *B D will be hauled free.*

TABLE 38. CONVERSION TABLE, LINEAL FEET TO MILES

1 to 9		10–90		100–900		1000–9000		10,000–90,000	
Feet	Miles	Feet	Miles	Feet	Miles	Feet	Miles	Feet	Miles
1	0.00019	10	0.00189	100	0.01894	1000	0.18939	10,000	1.8939
2	0.00038	20	0.00379	200	0.03788	2000	0.37879	20,000	3.7879
3	0.00057	30	0.00568	300	0.05682	3000	0.56818	30,000	5.6818
4	0.00076	40	0.00758	400	0.07576	4000	0.75758	40,000	7.5758
5	0.00095	50	0.00947	500	0.09470	5000	0.94697	50,000	9.4697
6	0.00114	60	0.01136	600	0.11364	6000	1.13636	60,000	11.3636
7	0.00132	70	0.01326	700	0.13258	7000	1.32576	70,000	13.2576
8	0.00152	80	0.01515	800	0.15152	8000	1.51515	80,000	15.1515
9	0.00171	90	0.01705	900	0.17046	9000	1.70455	90,000	17.0455

On material *A B* there will be paid overhaul. The average distance the material *A B* will be hauled will be the distance between the centers of gravity of *A B* and *D E* respectively.

Let X represent that distance. Then X minus 500 ft. equals the average length of overhaul.

9. The overhaul can also be computed from the area of the section *A B D E A;* this area represents the product of the material excavated in yards and the distance hauled. Find the area of the section *A B D E A* by a planimeter or otherwise. This area will be expressed as yard stations, and when divided by the ordinate *G B* in cubic yards will give the length of haul in stations.

Suppose the area *A B D E A* equals 2.5 square inches. Each square inch represents 200 cu. yds. $\times$ 5 stations, or 1,000 sta. yds. Therefore, an area of 2.5 square inches would represent 2,500 sta. yds. According to the diagram the total amount of dirt hauled equals 280 cu. yds. as measured on the ordinate *GB*. Therefore the average haul for this 280 cu. yds. equals $\frac{2{,}500 \text{ sta. yds.}}{280 \text{ cu. yds.}} = 8.9$ stations.

The free haul equals 500 feet, or 5 stations, therefore the overhaul equals $8.9 - 5 = 3.9$ stations. The amount of overhaul equals 280 cu. yds. $\times 3.9 = 1092$ sta. yds.

TABLE 39.[1] GIVING THE NUMBER OF POUNDS OF STONE PER 100 FEET OF ROAD FOR DIFFERENT DEPTHS OF LOOSE SPREAD AND DIFFERENT WEIGHTS OF STONE

12–FOOT ROAD

Weight of 1 cu. yd. Stone, Loose Measure	Depth of Loose Spread				
	2½"	3⅛"	3⅞"	5¼"	6½"
2250	20,800	26,000	32,300	43,700	54,200
2300	21,300	26,600	33,000	44,700	55,300
2350	21,800	27,100	33,700	45,700	56,600
2400	22,200	27,700	34,400	46,700	57,800
2450	22,700	28,200	35,200	47,700	59,000
2500	23,200	28,800	35,900	48,700	60,200
2550	23,600	29,400	36,600	49,600	61,400
2600	24,100	30,000	37,300	50,600	62,600

[1] *NOTE. — The quantities in this table are figured by slide rule but are sufficiently close for the purpose to which the table is put.*

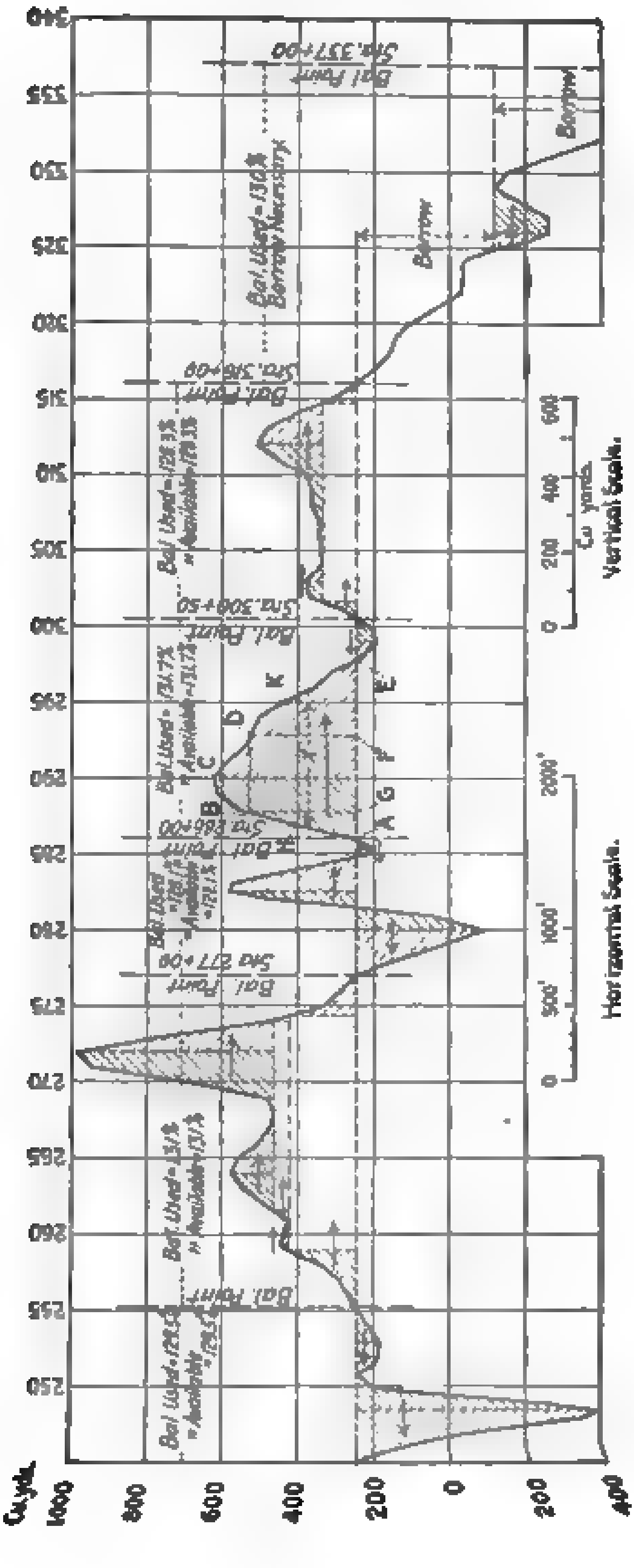

Cu. yds.
Bal. Point
Sta. 337+00
Sta. 318+00
Sta. 300+50
Sta. 277+00
Borrow
Horizontal Scale.
Vertical Scale.
Cu. yards.

FIG. 64

TABLE 39. — *Continued*

Weight of 1 cu. yd. Stone, Loose Measure	Depth of Loose Spread				
	2½"	3⅛"	3⅞"	5¼"	6½"
14-FOOT ROAD					
2250	24,300	30,400	37,700	51,000	63,200
2300	24,800	31,000	38,500	52,200	64,600
2350	25,400	31,700	39,300	53,300	66,100
2400	25,900	32,400	40,200	54,400	67,500
2450	26,400	33,000	41,000	55,600	68,900
2500	27,000	33,700	41,800	56,700	70,300
2550	27,600	34,400	42,700	57,800	71,600
2600	28,100	35,100	43,500	59,000	73,000
15-FOOT ROAD					
2250	26,000	32,600	40,400	54,700	67,700
2300	26,600	33,200	41,300	55,900	69,200
2350	27,200	34,000	42,200	57,200	70,800
2400	27,800	34,700	43,100	58,400	72,200
2450	28,400	35,400	44,000	59,600	73,800
2500	29,000	36,100	44,800	60,800	75,200
2550	29,500	36,900	45,800	62,000	76,700
2600	30,100	37,600	46,700	63,200	78,200
16-FOOT ROAD					
2250	27,800	34,700	43,100	58,400	72,300
2300	28,400	35,500	44,000	59,600	73,900
2350	29,000	36,300	45,000	60,900	75,500
2400	29,600	37,000	45,900	62,200	77,200
2450	30,200	37,800	46,900	63,600	78,700
2500	30,900	38,600	47,800	64,900	80,300
2550	31,500	39,400	48,800	66,200	82,000
2600	32,100	40,100	49,800	67,400	83,600

The computation of earthwork is the longest operation of the quantity estimate. When this is finished the quantity estimate is considered as practically complete.

TABLE 40. GIVING THE NUMBER OF CUBIC YARDS OF MACADAM PER 100 FEET OF ROAD FOR DIFFERENT WIDTHS AND DEPTHS

Width of Macadam	Depth							
	2"	2½"	3"	3½"	4"	5"	6"	7"
10'	6.17	7.71	9.26	10.80	12.34	15.43	18.52	21.61
12'	7.41	9.26	11.11	12.96	14.82	18.52	22.22	25.93
14'	8.64	10.80	12.96	15.12	17.28	21.61	25.92	30.25
15'	9.26	11.58	13.89	16.20	18.52	23.16	27.78	32.41
16'	9.88	12.35	14.81	17.28	19.76	24.70	29.63	34.57
18'	11.11	13.90	16.67	19.44	22.22	27.79	33.34	38.89
20'	12.35	15.44	18.52	21.60	24.70	30.87	37.04	43.21
22'	13.58	16.98	20.37	23.76	27.16	33.96	40.74	47.53

The other quantities figured are: length of road in miles. Table 38 converts lineal feet to miles.

Quantities of macadam, sub-base, concrete paving foundations, square yards of surfacing, which are simple computations involving length, width, and depth: Tables 39, 40, and 41 can be conveniently used.

Quantities of oil or other surface or penetration treatments, which are usually specified as gallons, per square yard: Table 42 is developed with this in view.

Concrete for culverts or retaining walls. Where a large amount of work is done it generally pays to compile a table of quantities for standard culverts of different sizes and lengths. The quantities can then be picked from these tables sufficiently close for a preliminary estimate. There would be no object in including in a book of this character any table suitable for certain culverts, as each department has a different standard.

Expanded metal and reinforcing bars, Tables 15 and 16 cover these features.

Weights of cast-iron pipe: Table 14 can be used.

Incidentals requiring ordinary arithmetical computations only.

The quantity estimate being completed, the estimate of cost is made. This is considered in chapter X.

Construction Plans. The construction plans should give sufficient information to show the contractor what he is expected to do and to enable the constructing engineer to stake out and to build the road.

A finished set of plans consist of a map, profile, and cross-sections showing the alignment in relation to the preliminary survey line, the proposed grade elevations, the shape of the finished road, the widths and depths of road metaling, the crowns to be used, the existing structures and the proposed structures,

and all the minor points of design. Each Department has its own method of giving this information, and it makes little difference how it is shown so long as it is complete and clear. In general it may be said that the scales used are the same as in mapping the preliminary survey and that the size of sheets or rolls must be convenient to handle in the field; sheets larger than 24″ × 30″ are clumsy.

Miscellaneous Points. A point often overlooked in laying a grade line is the proper approach to a railroad grade crossing where the track is on a curve and has a superelevated rail. Where the road grade is level, or nearly level, the solution is comparatively simple, as shown in Fig. 65; but where the grade

FIG. 65

of the road is in an opposite direction to the elevation of the rail it is more difficult and sometimes impossible to make an easy riding crossing.

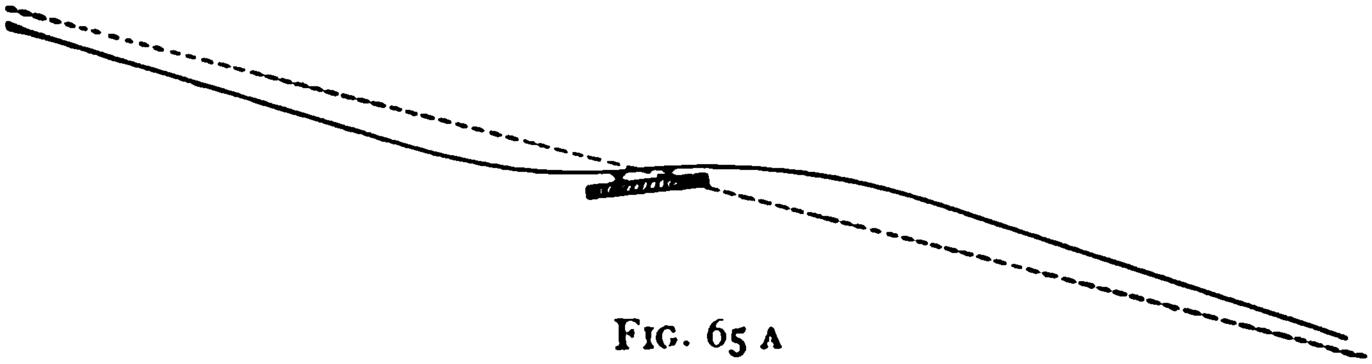


FIG. 65 A

Also, where a road, on a steep grade, crosses the railroad track on a large skew angle, care must be taken to flatten the grade near the track to avoid distorting the road section due to the difference in the rate of grade of the track and road. See Fig. 66.

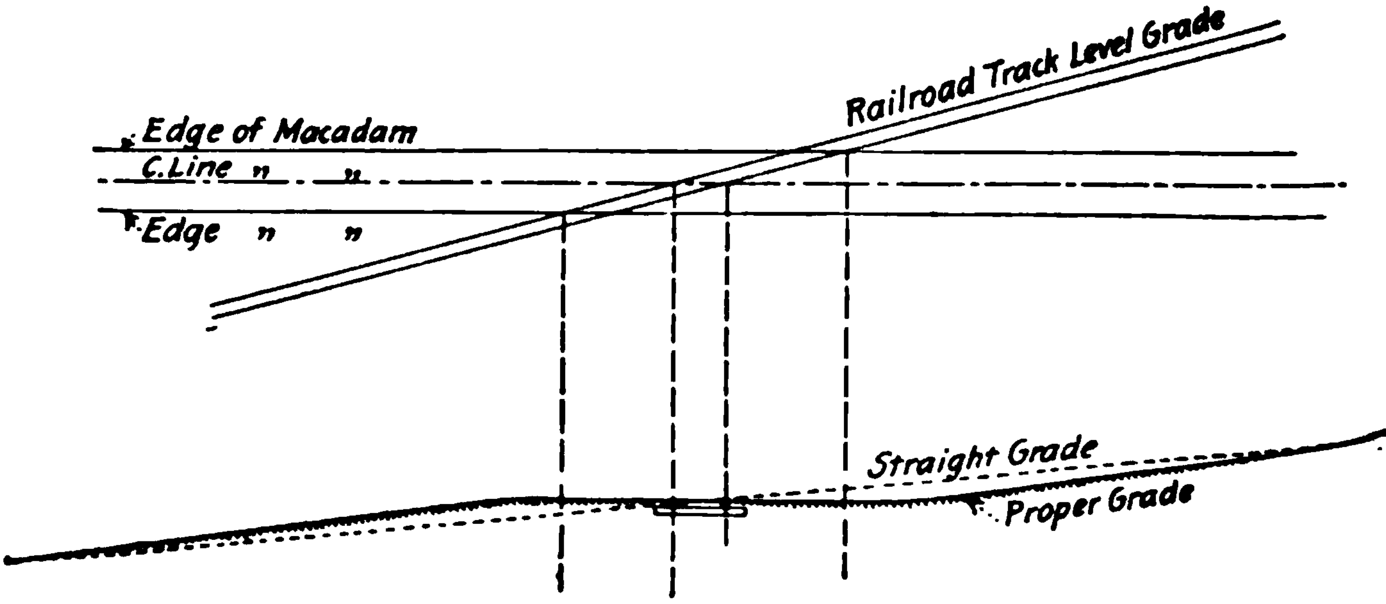


FIG. 66

Grade Crossing Eliminations. In grade crossing elimination lesigns the following minimum clearances have been adopted, Div. 5, N. Y. S. Dept. of Highways.

Where a highway is to be built under a railroad the crown elevation is made 13.5′ below the bottom of the bridge girder, and the minimum right-angle distance between abutments is taken as 26 feet. For solid floor railroad through girder bridges a clearance of 13.5′ below the bottom of the girder means a distance of from 16.5′ to 17.0′ below the top of the rail.

The tables (pp. 222–3) are taken from Spofford's "Theory of Structures," and a pamphlet issued by Heath & Milligan, of Chicago. They show the approximate weight of through girder railway bridges with the depth of floor system. They are useful for preliminary estimates on grade crossing elimination.

The weights given are for the steel only; the weight of the floor system must be added. For purposes of a rough preliminary estimate of cost the superstructure can be assumed to cost $60.00 per ton in place including all erection costs.

Where the highway crosses over the railroad a minimum clearance of 21.0′ is used from the top of rail to the bottom of the highway bridge; the span varies with the number of tracks. In determining the length required it is best to get in touch with the railroad engineers.

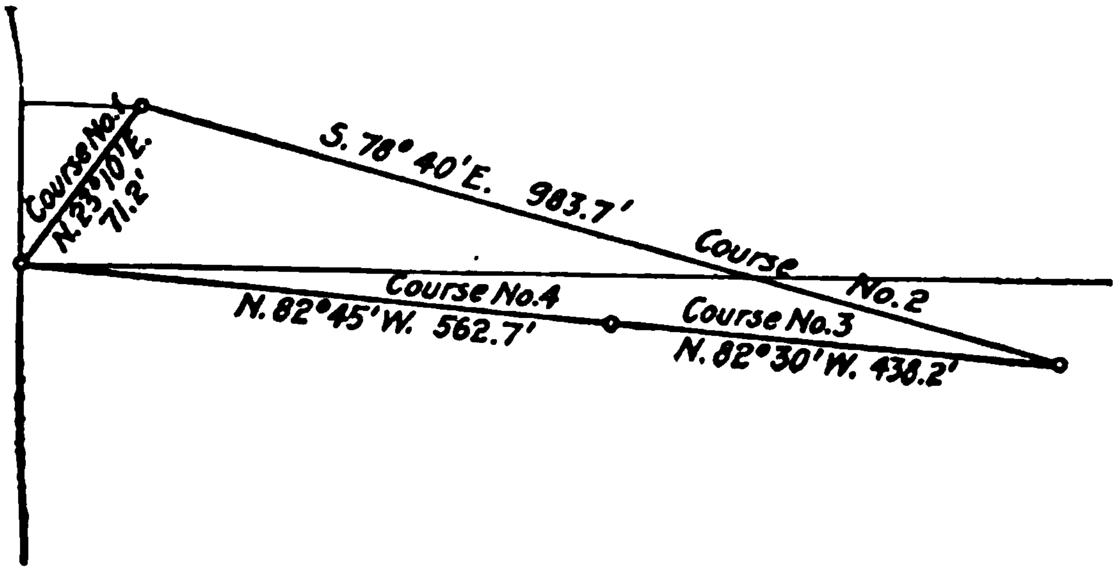
Right of Way Computations. The form of traverse computation and closure was shown on page 128.

The areas of rights of way are generally figured by dividing the parcel into rectangles, trapezoids, triangles, sectors, or segments, and figuring these shapes from the formulæ given in Table 57. These areas are checked by planimeter. They are usually figured to the nearest 0.01 acre.

The method of double-meridian distances can, however, be used if desired. The following formula and example are given to illustrate this method. It is not often necessary and is a tedious computation:

The rule is:

Twice the area of the figure is equal to the algebraic sum of the



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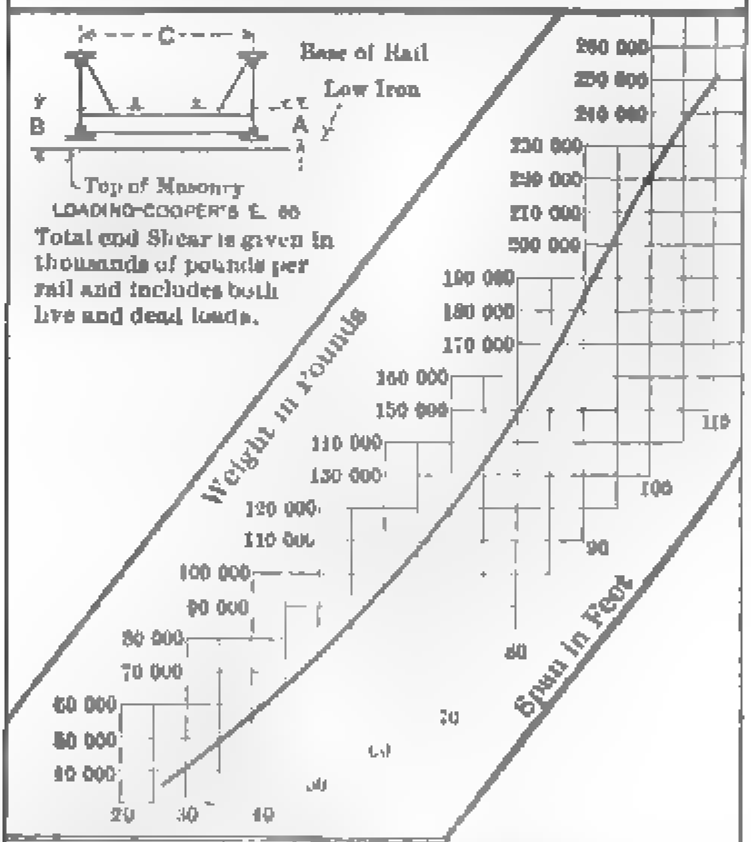
products of the double-meridian distances of each course multipl by its latitude.

In which the double-meridian distance equals the sum of t meridian distances of the two ends of each course referred to t meridian drawn through the most westerly point of the parc and the latitude of each course is reckoned as plus if the cou

THROUGH PLATE GIRDER SPANS, I-BEAM FLOOR
WEIGHTS, DIMENSIONS, ETC.



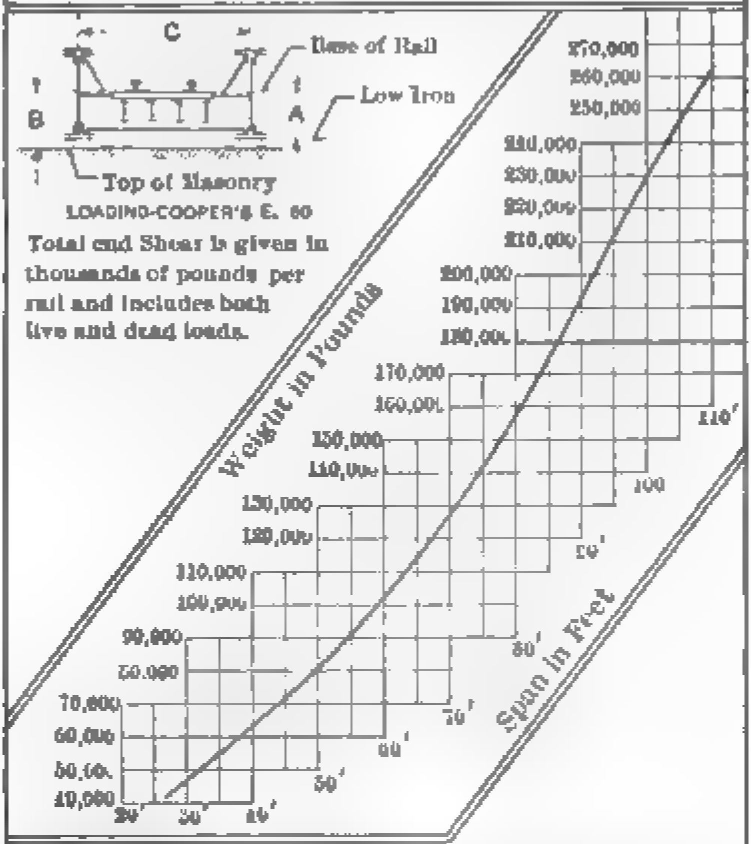
Span	Total End Sh.	A	B	C
30 ft.	106.2	2-2	2-2	15-0
35	117.1	"	"	16-0
40	128.7	"	"	17-0
45	141.1	2-4½	2-2½	17-4
50	162.2	"	"	"
55	162.1	2-1	2-9	"
60	1?1.2	"	"	"
65	186.2	"	"	"
70	190.3	2-5½	3-0	"
75	222.0	"	3-1½	"
80	226.4	"	"	"
85	240.5	"	"	"
90	257.4	"	"	"
95	265.7	"	"	"
100	284.0	3-4	"	"
110	304.0	3-4½	"	"

Erector's Note:
W = Total weight of one single track span with two light girders.

Span	Weight of one light girder	Weight of one heavy girder	Weight of one floor system
30' to 50'	.42 W	.30 W	.36 W
55 " 60'	.57 W	.48 W	.47 W
65 " 110'	.51 W	.57 W	.38 W

north and minus if it runs south. Take as an example the of way parcel shown in Fig. 50, page 128 for which the rse has been figured and refer the meridian distances to meridian drawn through the corner 3.1′ distant from station + 71.7.

THROUGH PLATE GIRDER SPANS, STRINGER FLOOR.
WEIGHTS, DIMENSIONS, ETC.



Span	Total End Sh.	A	B	C
30 Ft.	108.7	1′3″	3′6″	15′6″
35	122.0	1′3½″	1′3½″	15′6″
40 "	133.2	"	"	17′0″
45 "	144.7	"	"	"
50 "	156.0	"		"
55 "	167.5	2′6″	3′11″	"
60 "	178.3	"	"	"
65 "	191.1	2′1½″		"
70 "	204.7	"	"	"
75 "	[illegible]	"	4′0″	"
80 "	218.8	"	"	"
85 "	219.0	"		"
90 "	262.3	3′0″		"
95 "	277.6	"		"
100 "	291.2	3′6″		"
110 "	319.6	"		

Erector's Note.
W = Total weight of one single track span with two light girders.

Span	Weight of one light girder.	Weight of one heavy girder.	Weight of one floor system.
30′ to 50′	[illegible] W	[illegible] W	.52 W
50′ to 80′	[illegible] W	.46 W	.50 W
80′ to 110′	.25 W	.31 W	.44 W

Example of Double-meridian distance Area Computation of the Parcel shown in Fig. 50, page 128. And figure on bottom of page 221.

Course Number	Bearing	Dist.	N	S	E	W	Lat.	D. M. D.	+ Areas	− Areas
1	N 23° 10′ E	71.2	65.4	—	28.0	—	+ 65.4	28.0	1,831	—
2	S 78° 40′ E	983.7	—	193.3	964.5	—	− 193.3	1020.5	—	197,263
3	N 82° 30′ W	438.2	57.2	—	—	434.5	+ 57.2	1550.5	88,688	—
4	N 82° 45′ W	562.7	71.0	—	—	558.2	+ 71.0	558.2	39,632	—

197,263 sq. ft. − 130,151 sq. ft. = 67,112 sq. ft.
This equals twice the area of the parcel.

$$\text{Area of parcel} = \frac{67112}{2 \times 43{,}560} = 0.770 \text{ acres.}$$

rabolic Crowns for Pavements.
is often convenient to have the following data on parabolic n ordinates in making templets for pavement work.
vide the distance from the center of the road to the curb lging into ten equal parts and call the total crown 1.0; the nce down to the surface of the pavement from the crown .tion at each of these ten points expressed in terms of the crown will be

Center of Road, point No.	0	..........0.00
	1	..........0.01
	2	..........0.04
	3	..........0.09
	4	..........0.16
	5	..........0.25
	6	..........0.36
	7	..........0.49
	8	..........0.64
	9	..........0.81
Curb point	10	..........1.00

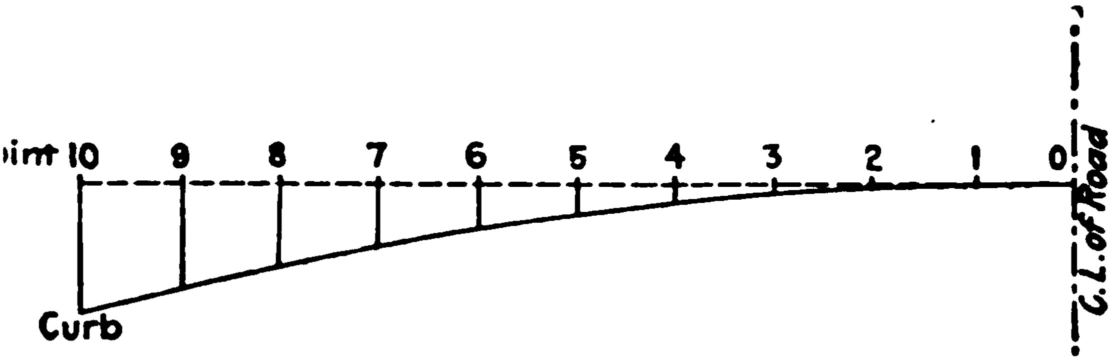


TABLE 41

ɪᴇ YARDS PER 100 FEET AND PER MILE FOR DIFFERENT WIDTH OF SURFACE

h t	Number of Square Yards Per 100 Feet	Number of Square Yards Per Mile	Width in Feet	Number of Square Yards Per 100 Feet	Number of Square Yards Per Mile
	88.889	4,693	26	288.889	15,253
	111.111	5,867	28	311.111	16,427
	133.333	7,040	30	333.333	17,600
	155.556	8,213	32	355.556	18,773
	166.667	8,800	34	377.778	19,947
	177.778	9,387	36	400.000	21,120
	200.000	10,560	38	422.222	22,293
	222.222	11,734	40	444.444	23,466
	244.444	12,907	42	466.667	24,640
	266.667	14,080	44	488,889	25,813

TABLE 42. GALLONS PER 100′ OF ROAD FOR DIFFERENT WIDTHS AND RATES OF APPLICATION

Width in Feet	Number of Gallons to the Square Yard											
	0.1	0.2	0.25	0.3	0.33⅓	0.4	0.5	0.6	0.66⅔	0.7	0.8	0.9
8	8.89	17.78	22.22	26.67	29.63	35.56	44.44	53.33	59.26	62.22	71.11	80.00
10	11.11	22.22	27.77	33.33	37.04	44.44	55.56	66.67	74.08	77.78	88.89	100.00
12	13.33	26.67	33.33	40.00	44.45	53.33	66.67	80.00	88.89	93.33	106.67	120.00
14	15.56	31.11	38.89	46.67	51.85	62.22	77.78	93.33	103.71	108.89	124.44	140.00
15	16.67	33.33	41.67	50.00	55.56	66.67	83.33	100.00	111.11	116.67	133.33	150.00
16	17.78	35.56	44.44	53.33	59.26	71.11	88.89	106.67	118.52	124.44	142.22	160.00
18	20.00	40.00	50.00	60.00	66.67	80.00	100.00	120.00	133.33	140.00	160.00	180.00
20	22.22	44.44	55.56	66.67	74.07	88.89	111.11	133.33	148.15	155.56	177.78	200.00
22	24.44	48.89	61.11	73.33	81.48	97.78	122.22	146.67	162.97	171.11	195.56	220.00
24	26.67	53.33	66.67	80.00	88.89	106.67	133.33	160.00	177.78	186.67	213.33	240.00
26	28.89	57.78	72.22	86.67	96.29	115.56	144.44	173.33	192.60	202.22	231.11	260.00
28	31.11	62.22	77.78	93.33	103.70	124.44	155.56	186.67	207.41	217.78	248.89	280.00
30	33.33	66.67	83.33	100.00	111.11	133.33	166.67	200.00	222.22	233.33	266.67	300.00
32	35.56	71.11	88.89	106.67	118.51	142.22	177.78	213.33	237.04	248.89	284.44	320.00
34	37.78	75.56	94.44	113.33	125.92	151.11	188.89	226.67	251.86	264.44	302.22	340.00
36	40.00	80.00	100.00	120.00	133.33	160.00	200.00	240.00	266.67	280.00	320.00	360.00
38	42.11	84.44	105.56	126.67	140.73	168.89	211.11	253.33	281.40	295.56	337.78	380.00
40	43.33	88.89	111.11	133.33	148.14	177.78	222.22	266.67	296.30	311.11	355.56	400.00
42	45.56	93.33	116.67	140.00	155.55	186.67	233.33	280.00	311.12	326.67	373.33	420.00
44	48.89	97.77	122.22	146.67	162.96	195.56	244.44	293.33	325.92	342.22	391.11	440.00

GALLONS PER 100 OF ROAD FOR DIFFERENT WIDTHS AND RATES OF APPLICATION — *continued*

Width in Feet	Number of Gallons to the Square Yard											
	1.0	1.1	1.2	1.25	1.3	1.33⅓	1.4	1.5	1.6	1.66⅔	1.7	1.8
8	88.89	97.78	106.67	111.11	115.56	118.52	124.44	133.33	142.22	148.15	151.11	160.00
10	111.11	122.22	133.33	138.89	144.44	148.15	155.56	166.67	177.78	185.19	188.89	200.00
12	133.33	146.67	160.00	166.67	173.33	177.78	186.67	200.00	213.33	222.22	226.67	240.00
14	155.56	171.11	186.67	194.44	202.22	207.41	217.78	233.33	248.89	259.26	264.44	280.00
15	166.67	183.33	200.00	208.33	216.67	222.22	233.33	250.00	266.67	277.77	283.33	300.00
16	177.78	195.56	213.33	222.22	231.11	237.04	248.89	266.67	284.44	296.30	302.22	320.00
18	200.00	220.00	240.00	250.00	260.00	266.67	280.00	300.00	320.00	333.33	340.00	360.00
20	222.22	244.44	266.67	277.78	288.89	296.30	311.11	333.33	355.56	370.37	377.78	400.00
22	244.44	268.89	293.33	305.56	317.78	325.93	342.22	366.67	391.11	407.41	415.56	440.00
24	266.67	293.33	320.00	333.33	346.67	355.56	373.33	400.00	426.67	444.44	453.33	480.00
26	288.89	317.78	346.67	361.11	375.56	385.19	404.44	433.33	462.22	481.48	491.11	520.00
28	311.11	342.22	373.33	388.81	404.44	414.82	435.56	466.67	497.78	581.51	528.89	560.00
30	333.33	366.67	400.00	416.67	433.33	444.44	466.67	500.00	533.33	555.55	566.67	600.00
32	355.56	391.11	426.67	444.44	462.22	474.08	497.78	533.33	568.89	592.58	604.44	640.00
34	377.78	415.56	453.33	472.22	491.11	503.71	528.89	566.67	604.44	629.62	642.22	680.00
36	400.00	440.00	480.00	500.00	520.00	533.33	560.00	600.00	640.00	666.67	680.00	720.00
38	422.22	464.44	506.67	527.78	548.89	562.97	591.11	633.33	675.56	703.70	717.78	760.00
40	444.44	488.89	533.33	555.56	577.78	592.60	622.22	666.67	711.11	740.73	755.56	800.00
42	466.67	513.33	560.00	583.33	606.67	622.22	653.33	700.00	746.67	777.78	793.33	840.00
44	488.89	537.78	586.67	611.11	635.56	651.85	684.44	733.33	782.22	814.81	831.11	880.00

CHAPTER X

COST DATA AND ESTIMATES[1]

New methods of construction have so changed the cost of road improvements that engineers just going into this work, or those not familiar with present methods, are often handicapped in making estimates.

The cost data given in this chapter has been gathered chiefly since 1907 and covers most of the items necessary for estimating the cost of any ordinary road improvement. Such data must be used intelligently or it will be misleading. Local conditions should always govern in making estimates, and in presenting costs it is best to describe the conditions under which the work was performed, leaving their special application to the one using the data. An engineer's estimate should represent the probable average bid price. In the following examples of actual cost those have been selected that are considered to be average cases. Contractors who have an unusually good plant and a well-organized force can often do the work cheaper than is shown; on the other hand, those new to the work will spend more.

Where machinery is used it is more satisfactory to include the items of depreciation, repairs, and interest in a lump-sum item for the whole contract than to try to reduce it to a yardage basis. These charges will be considered under the heading of "Plant and Pay Roll."

BITUMINOUS AND WATERBOUND MADACAM CONSTRUCTION

Cost of Earth Excavation.

Table 43 shows the cost of earthwork on four roads in New York State, which represent easy, average, and difficult work. The cost per cubic yard includes excavation and placing in fill, shaping the subgrade for the stone, and trimming the shoulders and ditches. For heavy fills with short hauls wheeled scrapers were used, but the largest part of the work was done by wagons.

Cost of Rock Excavation.

The writer has no reliable personal data on ledge rock excavation. Rockwork on roads is usually a small item; the cuts are small and consequently expensive. Perhaps there is no item more variable in cost than small rock cutting. It is therefore safer to take as a basis of estimate the bids of experienced road

[1] *Much of the data in this chapter was contributed by the author to the Engineering News* and published July 13, 1911.

TABLE 43. EARTH EXCAVATION

Road No.	Length, Miles	Total Excavation Cu. Yds.	Wages per Hour		Cost per Cu. Yd.	Kind of Soil	Engineer
			Men	Teams			
1[1]	2.5	8,600	$0.175	$0.45	$0.452	Loam and gravel, easy work	E. E. Kidder
2	5.5	28,000	0.175	0.45	0.484	Largely clay, hard excavation	S. O. Steere
3	6.0	18,000	0.15	0.45	0.46	Gravel, sand, clay, loam, etc., average work	W. G. Harger
4[1]	4.0	10,000	0.175	0.40	0.65	25% of excavation, small boulders, unusually hard excavation	W. G. Harger

[1] The cost of trimming the shoulders on road No. 1 was $345.00 per mile; on road No. 4, $700.00 per mile.

contractors. The reports of the Massachusetts Highway Commission and bids on New York State work show that prices for rock excavation range from $1.50 to $2 per cubic yard, for quantities up to 200 or 300 cu. yds., and $1.25 to $1.50 for larger quantities.

Cost of Unloading Broken Stone.

For making estimates of the quantity of stone required the following data on imported limestone used on Road 5,021 will be useful. The approximate sizes and actual weights of stone on this work were as follows:

No. 1 Screenings, $\frac{3}{8}$ inch screen	2,550 lbs. per cu. yd.
No. 1A Dustless screenings, $\frac{5}{8}$ in. screen with dust jacket	2,350 " " " "
No. 2, 1 in. screen	2,470 " " " "
No. 3, 2 " "	2,350 " " " "
No. 4, 3½ " "	2,420 " " " "

For purposes of estimating the cost of handling imported crushed stone, the following weights for a cubic yard, based on railroad weights, will be used: No. 1, 2,600 lbs.; No. 1A, 2,400 lbs.; No. 2, 2,500 lbs.; No. 3, 2,400 lbs.; No. 4, 2,400 lbs.

Unloading Cars by Hand.

On Road 5,021, with the author as engineer, a number of short time (10-hr.) estimates made the cost of unloading per ton $0.12 to $0.135; and the cost per cubic yard $0.14 to $0.16. This work was in 1910, and labor cost $0.175 per hour. The shoveling was done from a steel platform, where it was dumped from hopper-bottom cars. When shoveled from inside the cars the cost may run as high as $0.20 per cu. yd. The cost of shoveling is usually estimated at $0.15 per cu. yd.

The time of loading 1½ cu. yd. wagons by hand shoveling will range from 8 to 12 minutes.

Unloading Cars with Continuous Bucket Conveyor Elevator Plant.

Where there is a large quantity of stone to be unloaded and it is not possible to install an elevator plant on the existing track, it often pays to put in a switch. Six cars switches can be usually built for about $300.00. Where there are competing railroads no charge is usually made.

The following data is from Road No. 5,046, season of 1910, with labor at $0.175 per hour. The plant consisted of an ordinary continuous bucket conveyor operated by a 6 H.P. gasoline engine; the bin had a capacity of 100 tons.

The average fuel consumption was five gallons of gasoline per day. Cost of fuel and oil averaged $1.00 per day.

The average force at the elevator was one foreman and three helpers.

A total of 4,670 tons, or 3,890 cu. yds., was unloaded at $0.084 per ton, or $0.101 per cu. yd.

cost was divided as follows:

Setting up elevator at Scottsville	$ 60.00
" " " " Mumford	40.00
" " " " Wheatland	75.00
Labor of operation	194.00
Gasoline and oil....................	25.00
Total......	$394.00

; method of unloading is not only cheaper than hand ds but also cheapens the cost of hauling, as no time is lost ling the wagons. The time of loading a 1¼ cu. yd. wagon ›ins ranges from 45 to 55 seconds. There is also a saving demurrage if the bin holds two or three car-loads.

ator unloading saves about $0.04 per cu. yd. on team time ›out $0.05 on the unloading, making a total saving per yard of about $0.09. It usually costs about $150 to ship ant and install it the first time, so elevator unloading is opted unless there are, at least, 2,000 cu. yds. of stone :d.

ing Cars from Coal Trestle.

; data is taken from the Scottsville road repair work, arold Spelman, Engineer, season of 1910; labor at $0.20 ur; average force, two or three men. A total of 4,400 tons ıloaded. The cost divided as follows:

Rent of trestle	$125.00
Labor	232.00
Total	$357.00
Cost per ton	0.081
" " cu. yd..................	0.098

ing from Canal Boats.

plant used consisted of a portable bin and a horse-operated :; Road 5,014; Mr. James Anderson, contractor. The :e amount of stone unloaded per day was 150 tons. The 'as $0.115 per ton, or $0.14 per cubic yard, divided as ;:

team and driver	$ 4.00	(10-hour day)
foreman	2.50	" " "
laborers, at $1.75 per day	10.50	" " "
Total	$17.00	" " "

Hauling Broken Stone.

le 44 shows the cost of hauling stone on good roads as for work. The wagons were loaded from bins, so no time was loading.

TABLE 44.—HAUL OF STONE ON GOOD ROADS FOR REPAIR WORK

Road No.	Engineer in Charge	Price per Hour of Teams	Length of Haul, Miles	Cost per Ton, Mile	Cost per Yard, Mile
1	Harold Spelman	$0.50	1.8	$0.20	$0.24
1	Harold Spelman	0.50	1.2	0.24	0.288
2	G. G. Miller	0.62	2.0	0.20	0.24
2	G. G. Miller	0.62	1.7	0.215	0.26
2	G. G. Miller	0.62	1.1	0.23	0.275
2	G. G. Miller	0.62	0.6	0.25	0.30
2	G. G. Miller	0.62	0.2	0.50	0.60
3	G. G. Miller	0.62	3.0	0.17	0.205
3	G. G. Miller	0.62	2.75	0.175	0.21
3	G. G. Miller	0.62	2.5	0.175	0.21
3	G. G. Miller	0.62	2.0	0.19	0.23
3	G. G. Miller	0.62	1.75	0.215	0.26
3	G. G. Miller	0.62	1.5	0.23	0.28

Road No. 1, 10-hour day.
Roads No. 2 and 3, 8 hours per day.

NOTE.—Cost per ton mile on Roads No. 2 and 3 equals the cost per yard mile, for teams at $0.50 per hour.

For hauling on bad roads for new construction I have the following personal data:

Clover Street Road, Section 1, season 1908; teams at $0.45 per hour; dump wagons loaded from bins; no time lost.

6,000 cu. yds., 0.6 mile haul cost 26 cts. per ton, or 31 cts. per yard mile.

4,500 cu. yds., 0.6 mile haul, cost 24 cts. per ton, or 29 cts. per cubic yard mile.

Scottsville-Mumford Road, season of 1911; teams, $0.45 per hour. 300 cu. yds., 1 mile haul (including a 5 per cent sand hill 1,200 ft. long) cost $0.30 per yard mile.

500 cu. yds., 0.5-mile haul (level road in bad condition) cost $0.30 per yard mile.

Hauling Field Stone and Filler. This material was hauled from fields and pits where it was loaded by hand, and considerable time thus lost.

On the Clover Street Road, Section 1, season of 1908, with the author as Engineer, and teams at $0.45 per hour, 10,000 cu. yds. of field stone were hauled an average of one mile for $0.3 per yard mile.

On the Scottsville-Mumford Road, season of 1911, with the author as Engineer, and teams at $0.45 per hour, 500 yds. of field stone were hauled 0.2 mile at $0.14 per cu. yd., or $0.7 per yard mile. On the same work 200 cu. yds. of filler was hauled 0.2 mile for $0.15 per cu. yd., or $0.75 per yard mile.

For all short hauls under ½ mile the cost is high and practically the same on account of the larger percentage of time lost in loading.

Mechanical Hauling. This method has not come sufficiently into general use to be considered in estimating, in the writer's opinion, unless it is difficult to get teams. It rarely pays to use traction engines for less than a three-mile haul, even on a hard road. In case they are used a light engine or road-roller and a train of ordinary dump wagons are more satisfactory than a heavy engine and large 5 or 7 cu. yd. cars. For maintenance and repair work, however, some style of automobile truck will, doubtless, be used in the near future. Under favorable circumstances mechanical hauling will cost about 12 to 15 cents per yard mile.

Cost of Loading Local Fence Stone into Wagons.

Road No. 5,046, W. G. Harger, Engineer, season of 1911, Labor $0.175 per hour.
2,200 cu. yds., boulders loaded at a cost of $0.14 per cu. yd.

A gang of six men will take from 9 to 13 minutes in loading 1½ cu. yds., depending upon the size of the stone.

Road No. 495, E. E. Kidder, Engineer, season of 1911, Labor, $0.175 per hour.
1080 cu. yds., boulders loaded at a cost of $0.184 per cu. yd.

Road No. 492, E. E. Kidder, Engineer, season of 1911, Labor $0.175 per hour, 300 cu. yds., loaded at $0.137 per cu. yd.

COST OF SPREADING STONE AND BINDER

Table 45, page 234, gives the cost of spreading broken stone on several New York State roads.

The ratio of the loose to the rolled depths varies with the size of the fragments and the depth of the course. Table 46, page 234, gives the averages of the results obtained from 1,000 test holes made by the writer on three separate roads. The last column of the table also gives the weights of No. 3 and No. 4 stone required to make a cubic yard of rolled macadam. The amount of filler or binder per cubic yard of rolled macadam is given in Table 47, page 234.

The excessive amount of filler required for the 2-inch bituminous macadam, Table 47, was due to a layer of screenings placed under the No. 3 stone, all of which did not act as a filler. The small amount required for the 3-inch bituminous macadam was due to the fact that the bituminous binder partially filled the voids before the screenings were applied.

The ratio of loose to rolled depth for boulder sub-base is variable.

If the size of boulders is practically the same as the depth of the course, that is, if there is only one layer of stone, the loose depth and the rolled depth will be the same. Where there are

two or three layers of boulders the ratio is, approximately, 1:1.25, i. e., a 12-inch, rolled depth would require 15-inch loose depth for boulder averaging 5 to 6 inches in diameter.

TABLE 45.—SPREADING STONE

Reference No.	Engineer	Labor Wage	Depth of Loose Spread	Amount Spread	Cost per Ton	Cost per Cu. Yd.
1	Harold Spelman ..	$0.20	4 in.	7000 tons	$0.066	$0.08
2	W. G. Harger	0.175	5½ in.	6000 cu. yds.	0.05	0.06
2	W. G. Harger	0.175	4 in.	4500 " "	0.07	0.083
3	W. G. Harger	0.20	6 "	1000 " "	—	0.05
		Placing sub-base stone				
3	W. G. Harger	0.175	7 in.	100 " "	—	0.10
3	W. G. Harger	0.175	10 " gravel	200 " "	—	0.04
4	E. E. Kidder......	0.175	6 "	267 " "	—	0.07
[1]5	E. E. Kidder.. ...	0.175	6 "	1082 " "	—	0.12

TABLE 46.—RATIO OF LOOSE TO ROLLED DEPTH

Size of Stone	Rolled Depth	Loose Depth	Ratio	Weight per Cubic Yard Rolled Measure[2]
No. 4	4 in.	5.2 in.	1.3	3120 lbs.
No. 4	3 "	3.8 "	1.27	3050 "
No. 3	3 "	3.9 "	1.3	3120 "
No. 3	2 "	2.4 "	1.2	2880 "

TABLE 47.—AMOUNT OF FILLER AND BINDER REQUIRED

Kind of Course	Kind of Filler	Amount of Filler per Cu. Yd. of Rolled Macadam	Weight of Screenings per Cu. Yd. of Rolled Macadam
Bottom stone	Sand	0.35 cu. yds.	—
Waterbound top[3]...	No. 1	0.50 " "	1300 lbs.
3-in. Bit. mac. top[3].	Nos. 1A and 2	0.37 " "	900 "
2-in. Bit. mac. top[3].	No. 1A	0.60 " "	1440 "
Sub-base	Gravel	0.33 " "	—

[1] Sub-base bottom course. The cost includes sledging of all large stone.
[2] Weight of cubic yard loose 2,400 lbs., as noted at the beginning of the chapter.
[3] Weight of cubic yard loose 2,400 lbs. Filler for top course includes wearing coat.

Cost of Loading Filler at Pit. On the Clover Street Road, Section 1, during the season of 1908, with the author as engineer and labor at $0.15 per hour, 400 cu. yds. of sand filler were loaded at a cost of $0.12 per cu. yd. On the Scottsville-Mumford Road, with labor $0.175 per hour, 200 cu. yds. were loaded at a cost of $0.13 per cu. yd.

Cost of Spreading Filler by Hand from Piles Spaced 20′ to 30′ Apart. On the Clover Street Road, Section 1, during the season of 1908, with labor at $0.15 per hour, 400 cu. yds. of sand filler were spread at a cost of $0.10 per cu. yd. On the Scottsville-Mumford Road, with labor at $0.175 per hour, the cost of spreading 200 cu. yds. was $0.20 per cu. yd. This includes some hand brooming, but most of the brooming was done by a broom attachment on the roller.

Cost of Spreading No. 1A and No. 2 Stone for Bituminous Macadam Top Courses and Brooming Same. A layer of No. 1A, ½ inch deep, was spread over the bottom course. On this was spread 2½ inches of No. 3 stone. After rolling bitumen was poured over this course and a ¾-inch layer of No. 2 stone spread and rolled; the excess of No. 2 was broomed off and a ⅜-inch wearing coat of No. 1A placed.

The cost of spreading for a 2-in. top was as follows:

Cost of No. 1A and No. 2 per cu. yd.	$0.282
Cost per ton of No. 1A and No. 2	0.210

Eight hundred tons of this material were handled with labor costing $0.175 per hour.

For a 3-in. top course the procedure was the same, omitting the layer of No. 1A under the No. 3 stone. The cost of handling 400 tons for the 3-in. course was as follows:

Cost per cu. yd of No. 1A and No. 2 ...	$0.31
Cost per ton of No. 1A and No. 2	0.26

Cost of Spreading Screenings with Cross Dump Wagons. Wet dust screenings for waterbound macadam cannot be successfully spread in this manner. For spreading dry dust screenings, No. 2 stone or dustless screenings for bituminous macadam, this method has proved the cheapest and most satisfactory. On Road 5,046, season of 1910, a number of short-time estimates made the cost of spreading by this method about $0.06 per cu. yd. The cost of brooming is slightly increased over that required by the hand-spreading method, but not enough to counteract the advantage in the use of the wagon spreading. On the Clover Street Road, season of 1908, 1,000 cu. yds. of screenings were thus spread for about $0.07 per cu. yd.

COST OF ROLLING

In the following costs lubricating oil is not included, as no reliable data was obtained as to the quantity used. Gillette's "Handbook of Cost Data" gives this item as $0.30 per day; using this amount would increase the costs given below from 0.2 to 0.3 of a cent per cu. yd. The amount of coal used was variously

estimated at from 450 to 500 lbs. per day. As before mentioned, items of depreciation, repairs of plant and equipment, and interest are not included in the cost per cubic yard of stone consolidated.

On Road 5,025, under Mr. E. E. Kidder, Engineer, during the season of 1910, the cost of rolling 3,400 cu. yds. of bottom stone and 1,700 cu. yds. of top stone, loose measure, was as follows:

Rollerman, 4 months, at $90	$360.00
Coal, ¼ ton per day, at $2.70 per ton, 80 days	55.00
	$415.00

The time and cost were divided as follows:

⅙ on subgrade	$ 69.00
⅓ on bottom stone 4″ deep	138.00
½ on bituminous top stone, 2″ deep	208.00

There was no cost for water. The roller worked 80 days in 4 months. The cost of rolling per cubic yard of loose material was: bottom stone, $0.04, and top (bituminous macadam) $0.12.

On Road 492, Mr. E. E. Kidder, Engineer, season of 1910, the cost of rolling 3700 cu. yds. of 4-in. bottom course was $0.03 per cu. yd., and for 3,200 cu. yds. of waterbound top stone $0.05 per cu. yd. Both quantities refer to loose measure. The roller worked 74 days in three months. The puddling was done by a pipe line and hose and brooms attached to the roller. The rollerman's wages were $90.00 per month and coal $2.75 per ton.

On Road 5,021 the cost of rolling a 3-in. bituminous top course per cubic yard of loose material was $0.09; for a 2-in. top $0.11.

On Road 5,046 a roller working 111 days consolidated 1,850 cu. yds. of field stone sub-base, 4,300 cu. yds. of bottom stone, and 2,150 cu. yds. of top stone, loose measure. The depth of the sub-base was 6 in. (rolled measure), the bottom course 4 in., and the top course 2½ in., bituminous macadam. The rollerman's wages were $90 per month and coal cost $2.75 per ton for ¼ ton per day. There was no cost for water. The costs were divided as follows: sub-base, $0.035; bottom stone, $0.045; top stone, $0.105 per cu. yd., loose measure.

COST OF CRUSHING STONE

As a basis for all cost estimates for crushing, it is necessary to know something of the percentage of the different sizes of the crusher output. Table 48, page 237, gives the results of tests made by Mr. Archer White during the season of 1910 on ordinary limestone and sandstone boulders composing the average field stone. The crusher used was the largest Acme portable crusher. The tailings were recrushed and the stone divided into four grades: No. 1, ¾-in. screen; No. 2, 1½-in.; No. 3, 2½-in., and No. 4, 3½-in. From this data it may be seen that 1 cu. yd. of field stone makes 1 cu. yd. of crushed stone, and that it takes approximately 1.8 cu. yds. of field stone to make 1 cu. yd. rolled measure of sizes Nos. 3 and 4. The crusher toggle was set to produce both top and bottom stone sizes.

TABLE 48.—SIZES AND PROPORTIONS OF CRUSHER RUN

Reference No.	Cu. Yds. Field Stone Delivered to Crusher	Cu. Yds. Crushed Stone Produced	Number 1		Number 2		Number 3		Number 4		Kind of Material
			Cu. Yds. Produced	% of Total Output	Cu. Yds. Produced	% of Total Output	Cu. Yds. Produced	% of Total Output	Cu. Yds. Produced	% of Total Output	
1	195	190	36	19	18	9	64	34	72	38	Sandstone and limestone
2	187	182	32	17½	10	5½	70	38½	70	38½	Limestone
3	196	202	36	18	14	7	76	38	76	37	Limestone and sandstone
4	190	216	40	18	18	8	79	37	79	37	Sandstone
5	173	172	32	19	28	16	62	36	50	29	Poor sandstone
6	189	184	36	19½	16	9	*	—	132	71½	Limestone
7	165	170	32	19	22	13	*	—	116	68	"
8	—	—	30	16	24	13	*	—	60	63	Soft sandstone

* No. 3 and No. 4 size mixed and placed on grade.

The cost of labor was \$0.20 per hour. The engineman of the crusher plant received \$0.25 per hour and the foreman \$0.30 per hour. The field stone was loaded from a pile near the crusher into small dump cars running on a movable track. The loaded cars were drawn to the crusher by a small hoisting engine. The cost of bringing the field stone to the crusher pile is not included. The force loading consisted of one foreman, eleven laborers, and one engineman. The force crushing consisted of one foreman, four laborers, and one engineman. In eight days 1,500 cu. yds. were crushed. The cost of the entire output per cubic yard of loose measure was divided as follows:

Loading stone for crusher	\$0.133
Hauling to crusher	0.013
Feeding to crusher	0.061
Engineer to crusher	0.013
Fuel and oil	0.030
Loading crushed stone from bins	0.010
Total	\$0.260

Crushing Granite Hardheads and Sandstone. The following data is from the records of the Clover Street Road, Section 1, season of 1908. Labor cost \$0.15 per hour and the engineman received \$3 per day. The crusher used was a 10" × 20" Climax. A total of 5,000 cu. yds. of granite were crushed at a cost per cubic yard, loose measure, of \$0.19; 7,000 cu. yds. of sandstone boulders were crushed at a cost of \$0.103 per cu. yd., loose measure. These figures are for the total output of the crusher and include the costs of feeding to the crusher, the pay of the engineman, coal, oil, but not the delivery to the crusher. On the Scottsville-Mumford Road under similar conditions the cost varied from \$0.13 for granite and sandstone to \$0.19 for granite hardheads per cubic yard of loose measure.

Crusher force on the Clover Street and Scottsville-Mumford roads as follows:

1 foreman	\$4.00
5 men feeding crusher	2.00 each
1 man tending screen	2.00
1 engineer	3.00
Fuel and oil	4.00

Where bottom stone alone is being crushed from local material the crusher is set to produce a larger amount of No. 4 stone, and the proportion of the screenings to the No. 3 and No. 4 size is different than given in Table 48.

In the following data from Road 5,046, Scottsville-Mumford, mentioned above, the No. 3 and No. 4 and tailings were used as the bottom course stone, the tailings being broken into proper sizes after the stone was spread by knapping hammers. The cost of knapping will vary from \$0.01 to \$0.03 per cu. yd. of

loose bottom stone, depending on the number of tailings produced. When the crusher is set correctly to deliver a good grade of stone for bottom course, this charge should not amount to over $0.01 per cu. yd. of total output and is properly chargeable against crushing, which increases the crushing costs given above from $0.13 to $0.14 and from $0.19 to $0.20.

The size of screens were $\frac{3}{8}''$, $1\frac{1}{4}''$, $2\frac{1}{2}''$, and $3\frac{1}{2}''$.

Crusher Set-up, No. 1. 60% Granite, 30% sandstone, 10% soft rock.

Total screenings, No. 1 .... 240 cu. yds.
" No. 2 .... no record
" No. 3, 4, and tailings .... 1,500 cu. yds.

Crusher Set-up, No. 2. 50% granite, 40% sandstone, 10% soft rock.

Total screenings .... 350 cu. yds.
" No. 2 .... no record
" No. 3, 4, and tailings .... 2,600 cu. yds.

For this same road the amount of field stone required per loose yard of bottom stone is shown by the following figures. Approximately 1.5 yard loads were drawn to and from crusher.

Date	Number Loads of Field Stone Crushed	Number Loads of No. 3 and No. 4 and Tailings Drawn from the Crusher
1911		
April 24	114	93
" 25	86	70
" 26	87	69
May 5	104	84
" 6	101	82
" 8	106	85
" 9	99	78
" 10	86	72
" 11	107	95
" 12	110	80
" 13	102	83
Totals	1102 loads 1653 cu.yds.	891 loads 1336 cu. yds.

On this work 1.24 cu. yds. field stone produced 1 cu. yd. loose measure bottom stone, and 1.61 cu. yds. field stone produced 1 cu. *yd. bottom* stone rolled measure.

Table 48, page 237, gives 1.8 cu. yds. field stone to 1 c rolled macadam, but this apparent difference is explain the fact that the tailings were recrushed and the crush closer to produce top as well as bottom stone, consequentl per cent of No. 1 and No. 2 is higher than for the data given.

Data obtained by Mr. Frank Bristow, First Assistant Eng New York State Department of Highways, indicates that 1 c of field stone produces 1.1 cu. yds. crushed stone when sepa by screens of ½", 1½", 2½", and 3½"; this is slightly more tha writer's experience has indicated.

When local stone is crushed for bottom only, the screenin used as filler for that course, and in a case of this kind it is sary to know how much additional filler must be estin Take the case of the Scottsville-Mumford Road (crusher s No. 2) given above. Twenty-six hundred cubic yards measure will consolidate under the roller to approxin 2,000 cu. yds. of rolled bottom stone. This will require 2,(0.35 = 700 cu. yds. filler. The amount of screenings pro in crushing 2,600 cu. yds. of bottom was 350 cu. yds., sh that for cases similar to the one given, half of the total required must be obtained from other sources.

Cost of Sledging Boulders. A certain percentage of the stone must be broken to reduce them to a proper size for cru This is done by blasting or sledging; where the boulders ne be broken only two or three times to reduce it to a usable sledging is the cheaper method. The cost of both of methods is so variable that any cases cited would not be of value. As given on page 260, under Standard Estimate author allows arbitrarily $0.40 per cu. yd. for all boulders act sledged or blasted, and in making estimates the per cent treated in this manner is approximated roughly.

As a matter of interest Gillette, in his cost data on rock gives the cost of sledging small sandstone boulders as ap mately 0.05 per cu. yd., and the cost of mud capping at 0.35 per cu. yd.

COST OF CRUSHING (continued)

The following data is taken from the Report of the M chusetts Highway Commission and refers to work do Newton, Mass. The crushed stone was divided into the fo ing sizes:

Tailings	205 cu. yds.	17.5%
2½" stone	692 cu. yds.	57 %
Screenings and 1"	300 cu. yds.	25.5%
Totals	1197	100 %

The material was cobblestones and labor probably cost *per hour, teams,* $0.45. The cost per cubic yard at the cr *was $0.445,* or $0.33 per ton.

The cost per cubic yard was divided as follows:

Teaming to crusher	$0.314	70.6%
Feeding to crusher	0.033	7.4%
Engineer of crusher	0.029	6.5%
Repairs, coal, oil, etc.	0.045	10.1%
Watchman	0.024	5.4%
Total	$0.445	100%

Material. Conglomerate.

Amount broken . . . . 1,288 cu. yds.
Amount broken per hour . . . . . . 8.9 " "

Divided as follows:

		Weight per cu. yd. loose
Tailings, 378 cu. yds.	29.3%	2,549 lbs.
2½" stone, 668 cu. yds.	51.9%	2,368 "
Screenings and 1", 242 cu. yds.	18.8%	2,727 "

ost per cu. yd. in bins at crusher $1.112
ost of per ton in bins at crusher 0.885

Divided as follows:

	Cost	Per Cent
Powder and repairs	$0.018	1.6
Labor drilling	.249	22.3
Sharpening drills and tools	.023	2.1
Breaking stone for crusher	.420	37.8
oading stone for crusher	.127	11.4
Hauling stone for crusher	.062	5.6
Feeding crusher	.053	4.7
ngineer for crusher	.038	3.5
oal, oil, and waste	.050	4.5
Moving and setting crusher	.023	2.1
Watchman	.049	4.4
Total	$1.112	100

Material. Greenish trap.

Amount broken . . . . 3,155 cu. yds.
Amount broken per hour . . . . . . 7.7 " "

Divided as follows:

		Weight per cu. yd. loose
Tailings, 1,004 cu. yds.	31.8%	2,457 lbs.
2½" stone, 1,618 cu. yds.	51.3%	2,383 "
1" stone, 323 cu. yds.	10.2%	2,277 "
Screenings, 210 cu. yds.	6.7%	2,585 "

ost per cu. yd. in bins at crusher $0.898
ost per ton in bins at crusher 0.745

Divided as follows:

	Cost	Per Cent
Labor, steam, drilling	$0.092	10.3
Coal, oil, waste, powder, etc.	0.084	9.4
Sharpening drills and tools	0.069	7.7

Breaking stone for crusher	0.279	31.0
Loading stone for crusher	0.098	11.0
Hauling stone for crusher	0.072	8.0
Feeding crusher	0.053	5.9
Engineer of crusher	0.031	3.4
Coal, oil, waste, and repairs of crusher	0.079	8.8
Other repairs	0.041	4.5
Total	$0.898	100

W. E. McClintock, Engineer, Chelsea, Mass., season 1887:

Labor	$0.20 per hour
Teams	0.45 " "

Material. Trap rock.

Amount broken .... 1,718 tons

Stone delivered at crusher by subcontractor for $0.75 per to

Cost.	Tools	$0.013
	Oil, waste, etc.	0.016
	Fuel	0.050
	Stone at crusher	0.750
	Crushing (labor)	0.194
	Total per ton	$1.023

Dustless Screenings. The construction of bituminous ma adams requires a dustless screening product referred o the beginning of the chapter as No. 1A; it is obtained by r screening the ordinary screenings (¾" product) to remove tl dust; the percentage of dust in the ordinary screenings will va according to the stone crushed and the setting of the crush jaws. The author has no reliable data for small crushing plant but through the courtesy of the Buffalo Cement Company tl following data is given for their output of limestone screenin at Buffalo, N.Y.

Size of screen opening for ordinary screenings	¾"
Size of dust screen openings	⅛"

Cu. yds. of dust for 1 cu. yd. ordinary screenings	0.3
" " " dustless screening 1 cu. yd. ordinary screening	0.6

The same data from the Leroy plant of the General Crushe Stone Company gives:

Size of screen openings for ordinary screenings	⅝" to 11/16
" " dust screen openings	¼" " 5/16
Cu. yd. of dust per cu. yd. ordinary screenings	33%
" " " Dustless screenings per cu. yd. ordinary screenings	67%

Percentage of screenings to total output for Leroy limeston approximates 15%.

The above furnished to the writer through the courtesy of th *General Crushed* Stone Company, of Easton, Pa.

COST OF STONE FILL BOTTOM COURSE

The following data is taken from Road 5,021, season of 1910; labor cost $0.175 per hour, teams $0.40 per hour.

The amount placed was 10,000 cu. yds. rolled measure. The average rolled depth was 1.1 ft. The surface was carefully brought to line and grade, allowing a variation of 1 in. either above or below, which inequality was taken out with the top stone. A 3 in. bituminous top course was placed directly on this fill. The top layer of bottom stone was sledged to reduce all stones to 8 in. or under. Flint stone was used to fill the top 6 in. and to surface the rough fill. The bottom course was of fence stone, hauled, on an average, about one-half mile. I estimate that one cubic yard rolled measure requires 1.25 cu. yds. loose. The cost of the bottom course per cubic yards rolled measure was $1.03, divided as follows:

Loading 1.25 cu. yds.	$0.19
Hauling 1.25 " " ½ mile	0.20
Placing 1.25 " " and rolling	0.24
Sledging	0.15
Flint	0.10
Cost of fence stone	0.15
Total, per cu. yd.	$1.03

Cost of Sub-base Bottom Course. Road 495, Parma Corners-Spencerport. E. E. Kidder, Engineer. 1,082 cu. yds. placed, average depth 6″. Not much sledging required.

Cost of stone, 1 cu. yd.	$0.10
Loading, per 1 " "	0.184
Hauling 1 mile	0.30
Laying, sledging and spreading filler	0.136
Rolling	0.02
Superintendence	0.02
Cost of filler in pit nothing (gravel used).	0.00
Loading ⅓ cu. yd.	0.04
Hauling ⅓ cu. yd. 1 mile	0.10
Total	0.90

COST OF APPLYING BITUMINOUS BINDER

The following data is taken from Road 5,021, season of 1910. Bituminous macadam, penetration method:

Labor.

Kettleman	$0.20 per hour
Spreaders	0.20 " "
Plain labor	0.175 " "
Teams	0.45 " "

Apparatus.

4 bbl. kettle (coal burner) .... Bitumen heated
2 bbl. " (wood burner) .... to 400° F.

12 ton Kelly roller . . . .
Spreading pots having a vertical slot ½" wide.

Organization.
Rollerman acting as foreman
1 Spreader
1 Kettleman
3 Laborers

Average speed 350 ft. of 16 ft. road, per day.

Quantities.

16,850 gals. laid in one coat covered 13,330 sq. yds., or gals. per sq. yd.

Cost per gal.	Unloading and hauling ½ mile	$0.0
	Heating	0.0
	Spreading	0.0
	Rolling and supervision	0.0
	Total	$0.0
Bituminous material f.o.b. Caledonia		0.0
	Total per gal.	$0.1

Second quantity.

Forty-two thousand gallons covered 24,000 sq. yds. in coat, an average of 1.75 gals. per sq. yd.

Cost per gal.	Unloading and hauling 1¾ miles	$0.0
	Heating	0.0
	Spreading	0.0
	Rolling and supervision	0.0
	Total	$0.0
Bituminous material f.o.b. Caledonia		0.0
	Total per gal.	$0.1

Cost of Applying Bituminous Binder. Road 5,046, *Pene tion Method.*

18,890 gals. spread on 12,378 sq. yds. in one coat, of 1.52 g per sq. yd.

Apparatus.
5 2 bbl. kettles (wood burners) Fuel. Used bbl. st and some extra wood.
1 10-ton Buffalo Pitts Roller.
Spreading hods.

Organization.	Per Hour
1 Foreman	$0.30
2 Pourers, each	0.25
5 Kettlemen, each	0.20
2 Spreaders of No. 2, each	0.20
4 Helpers, each	0.175

Labor of Placing. Cost per gallon.

Fuel	$0.001
Kettlemen	0.005
Pouring	0.003

Helpers	0.007
Supervision	0.002
Total	$0.018
Material f.o.b. Scottsville	0.093
Total per gal.	$0.111

Kentucky Rock Asphalt. I have the following data from the Clarence Center Road, Mr. John D. Rust, Engineer, collected during the season of 1910. In this work an 8-ton tandem roller was found to do better than a 6-ton tandem. The cost of handling, spreading, and rolling this material, from data of five days selected, varied from $0.033 to $0.036 per sq. yd.; the average being $0.034. The following may be taken as a typical analysis of this cost:

Abbreviations. L. Laborers.
F. Foreman.
T. Teams.
E. Roller engineer.

Asphalt $10.25 per ton f.o.b. unloading point.
Run of July 20, 1909.
69.22 tons hauled and placed.
1,730 sq. yds. covered.
80 lbs. asphalt per sq. yd.

5 L. at cars, 10 hours, at $1.50 each	$ 7.50
½ F. at cars at $2.25 per day	1.12
5 T. haul 2 miles at $4.00 per team	20.00
5 L. on wheelbarrows, 11 hours, each $0.15 per hour	8.25
1 T. at shredding machine	4.40
3 L. on rakes, 11 hours at $0.15 per hour	4.95
3 L. shoveling, 11 hours, at $0.15 per hour	4.95
1 F. at shredder, 11 hours at $0.225 per hour	2.48
1 E. on roller, 11 hours at $0.30 per hour	3.30
Total	$56.95

Cost per square yard, $0.033.

PUDDLING WATERBOUND ROADS

There are two methods of puddling:
First, by Pipe Line and Hose.
Second, by Sprinkling Carts.

In the first method a 1½-in. or 2-in. pipe line is laid along the road with taps every 200 to 300 feet. The road is wet down by a hose fastened to these taps and sprayed on by a nozzle, or the hose is fastened to a sprinkling attachment on the roller, which throws the water directly onto the wheels; this method is cheaper and more satisfactory than using sprinkling carts, but to work well a pressure of 125 lbs. should be maintained at the pump, which requires a better pumping apparatus than contractors usually have. A very satisfactory plant, used near Rochester, N.Y.,

consisted of a Gould Triplex Pump, operated by a 6-H.P. gasoline engine; the relief valve at the pump was set at 120 lbs.

The cost of such puddling on Road 492 for 3,000 cu. yds. of top course was $0.05 per cu. yd.; on Road 294 for 4,000 cu. yds. of top course it was $0.06. This cost includes pumping, helper tending hose, and rollerman. Brooms on the roller were used which materially reduced the cost of brooming the screenings. No charge for water, no allowance made for laying the pipe line; this last charge is included in the lump-sum item of installing plant for a waterbound road, page 255.

Gillette, in his handbook, gives sprinkling by carts approximately $0.10 per cu. yd. of top course, which includes sprinkling the subgrade as well as puddling the top course. As the subgrade is rarely sprinkled, his data reduced to the conditions cited on roads 492 and 294 would give approximately $0.06 per cu. yd. of top course. To this is added the cost of rolling, or about $0.04, which makes the cost of puddling by this method about $0.10 to $0.12, or about twice the amount of the first method.

Mr. E. A. Bonney, on the Hamburg-Buffalo road, from a metered supply of water, states the amount required to first puddle a 3-in. top course varies from 50 gals. to 55 gals. per cu. yd. of top course, and the amount needed for the second puddle will be considerably less.

Mr. H. P. Gillette states, in a monograph on the Economics of Road Construction, that 30 gals of water per cu. yd. will puddle a road. Mr. E. E. Kidder states that approximately 80 gals. are required per cu. yd. of top course for two puddles. The author's experience agrees with the larger quantities.

McClintock Cube Pavement. The general costs of this experimental pavement were given in chapter V. We here give the detailed cost of the vitrified clay cubes and clay-ash cubes only, as the concrete cubes have not worn satisfactorily.

Vitrified Shale Cubes. During 1909, 74,000 2½-in. vitrified shale cubes manufactured at Reynoldsville, Pa., were laid at a cost as follows:

Teams at $0.50 per hour.

74,000 cubes f.o.b. Reynoldsville	$231.25
Freight	68.41
Carting	67.00
Laying	20.00
Total	$386.66

NOTE. 331 sq. yds. were covered at a cost of $1.17 per sq. yd.

Clay and Ash Cubes. In 1910, cubes made of a local clay mixed with ashes and burned were tried in the effort to get a cheap, tough clay product. As far as known, this is the first time bricks made in this way have been used on roadwork.

The ash-clay process has been worked out and patented by *Karl Langenbeck*, of Boston, Mass. Many local clays used for *ordinary brick or* farm tile will not stand up under vitrification

without the addition of expensive, imported refractory clays; but the substitution of coal ashes for the more expensive clays has a similar effect and the cost is materially reduced. Some of the local clay was sent to Mr. Langenbeck, who turned out a few cubes that compare favorably in toughness with the best paving bricks on the market.

The Standard Sewer Pipe Company, of Rochester, N.Y., undertook to furnish 400,000 2-in cubes of this description for Mr. McClintock. It was necessary for them to experiment to determine a practical method of molding, the correct temperature to use, and the best proportion of ashes, which naturally raised the price above ordinary practice. In molding they used a modification of the ordinary pipe-molding machine, which produced a hollow square of cubes, at the rate of 30,000 cubes per hour. The scoring knives were so set that the cubes were nearly cut apart, leaving just enough uncut clay to hold them together during the burning, after which a light blow separated them cleanly. The toughness of the resulting cubes can probably be increased by further experiment; but the product was good, although not up to the standard of the sample cubes made by Mr. Langenbeck.

The cost of the ash-clay cubes was as follows:

400,000 cubes f.o.b. Rochester, N.Y.	$1,200.00	$0.711	per sq. yd.
Carting, six miles	247.75	0.147	" " "
Filler	27.00	0.016	" " "
Labor of laying	191.77	0.113	" " "
Roller	12.94	0.008	" " "
Total	$1,679.46	$0.995	" " "

NOTE. 1,688 sq. yds. covered
Labor, $0.22 an hour } for laying and carting.
Teams, $0.50 an hour }

Mr. McClintock has stated, in discussing the cost, that in large quantities he believes the cubes can be delivered f.o.b. at the plant for $1.50 per 1,000, which would reduce the cost as shown above to about $0.60 per sq. yd., and that the high cost of laying was due to the irregular shape of the first batch, due to not scoring the cubes deeply enough.

COST OF CONCRETE WORK

The following data will help in estimating the cost of small concrete jobs, such as culverts, walls, etc. This data was collected by Mr. E. E. Kidder during the season of 1908. Table 49 contains the theoretical proportions of cement, sand, and stone required for the three ordinary mixtures of concrete. These values were found by experience to agree with actual proportions very closely for ½" to 1½"-stone.

TABLE 49.—MATERIALS REQUIRED FOR 1 CU. YD. OF CONCRETE

Mixture	Cement	Sand	Stone
1-2-4	1.5 bbls.	0.4 cu. yds.	0.9 cu. yds.
1-2½-5	1.2 "	0.45 " "	0.92 " "
1-3-6	1.0 "	0.45 " "	0.95 " "

The amount of water used per cu. yd. of concrete will vary greatly. A plastic mixture usually requires about 30 gals. per cu. yd., according to Baker.

Where boulders are embedded in the foundations and side walls of small culverts similar to Plate 6, less cement, sand, and stone are required; our experience with work of this kind shows that only 0.8 to 0.9 bbls. of cement are needed per cu. yd. for the total amount of concrete in these culverts including cover and parapets. For all classes of work where boulders cannot be embedded these proportions are about right.

	Per Cu. Yd.
Forms (labor)	$0.58
Lumber	0.50
[1] Labor, mixing, and placing	1.18
[1] Foreman	0.20
[1] Broken stone, at crusher	0.90
[1] Hauling stone, one mile	0.30
Sand at pit at 65 cts. per cu. yd.	0.32
Hauling sand six miles	0.75
[1] Taking down forms	0.10
Cement at culverts	2.00
Total	$6.83

Labor, $0.15 per hour.
Concrete, hand-mixed.
200 cu. yds., placed in small culverts, averaging 12 to 15 cu. yds. each.

NOTE. The labor of placing the concrete is customarily sublet to masons for $2.00 per cu. yd.

Small Culverts.

Java Center Road. George A. Wellman, Engineer.

One hundred and sixty-one cu. yds. of concrete in culverts, averaging 12 to 20 cu. yds. each.

Boulders were embedded in the third-class concrete. Water only had to be hauled for 30 cu. yds. of concrete.

[1] *Items accurate; other items approximately correct.*

	Materials Total Quality	Materials Unit Cost	Materials Total Cost	Amt. Per Cu. Yd. of Concrete Material	Amt. Per Cu. Yd. of Concrete Costs
nt	138 bbls.	$1.12	$154.56	0.86 bbls.	$0.96
	60 cu. yds.	1.00	60.00	0.37 cu. yds.	0.37
ed stone	130 " "	1.55	201.50	0.80 " "	1.24
er	3 M	30.00	90.00		0.56
			Total		$3.13

s are f.o.b. unloading point; teaming of material included labor cost given below, except for sand, which cost $1.00 ed on the job. Concrete mixed and placed by hand.

Cost of Labor and Teaming	Total	Per Cu. Yd. of Concrete
ın	$93.00	$0.58
unloading stone from cars	20.00	0.12
, placing concrete, and removing forms	204.00	1.27
ters, building forms	75.00	0.47
ıg	182.00	1.13
Total Labor		$3.57
Total Material		3.13
Total		$6.70

Labor	$0.175	per hour
Teams	0.50	" "
Carpenters	0.25	" "
Foreman	0.30	" "

l Span Concrete Arch. The following information of 19-ft. span concrete arch was given by Mr. Charles M. ls, First Assistant Engineer, New York State Depart- of Highways. Arch was built at Pembroke, N.Y., by actor who was crushing stone at a quarry about one- le from the work. Cement was hauled three-quarters of a For the concrete a mixture of one part Portland cement, ts sand, and four parts stone was used. The old masonry nts and wings were left in place and faced with 8 inches rete held by dowels. The quantities were: Concrete, 120 .; steel bars, 4,500 lbs.; pipe railing, 200 lin. feet. The the work was as follows:

ber, including arch centers	$156.00	on job
	106.00	" "
nt	137.00	on siding, f.o.b.
	240.00	on job
and sand	90.00	
ng	78.00	f.o.b. siding
r	300.00	
Total	$1,107.00	

and on this job cost practically nothing but we have placed the cost at rder to avoid a misleading item.

Omitting the cost of railing this figure gives a cost of $8.57 per cu. yd. of concrete, including steel. This cost does not include salvage of lumber or overhead expenses of any kind. The contractor received $1,500.00 for the work, including the earth filling, for which he used quarry strippings. This filling cost about $50.00.

Guard-Rail. In the following data the labor cost alone is given, for the materials will vary so much at different times and places that any quotations would be of little value.

The style of rail erected is similar to sketch, page 86. Road 715, 9,760 lin. ft. were built at the following cost, according to S. O. Steere, engineer in charge: Post-hole auger-diggers and ordinary shovels were used; the holes were dug in medium hard clay; labor at $0.20 per hour, foreman $3.00 per day; unskilled labor used in painting fence.

Digging post holes, setting posts, nailing on rails (erecting fence complete):

Cost	$0.0428 per lin. ft.
Painting three coats	0.0094 " " "
Total for erecting and painting	$0.0522 " " "

Road 5,046, W. G. Harger, as Engineer. 2,448 lin. ft. Built by subcontractor, Max Weller.

Force: Max Weller acted as foreman. In this data he has been arbitrarily allowed salary of $4.00 per day $4.00

1 helper	2.50
1 helper	2.00
1 helper	1.75

Cost of erecting and painting complete, per lin. ft. $0.066.

In Report of 1901 the Massachusetts Highway Commission gives the following costs for repainting guard-rail:

Lineal feet of guard-rail painted	350,330
Cost of paint per gal. (freight not included)	$1.05
Cost of paint per lin. ft. of guard-rail	0.0084
Cost of paint and painting per lin. ft. of guard-rail	0.0165
Lin. ft. of guard-rail painted per gal.	134.4
No. gals. of paint used per lin. ft. of guard-rail	0.0077
Time required to paint one foot, in decimals of an hour	0.0269

Concrete Guard-Rail. Style of rail shown in sketch on page 87, chapter on Minor Points.

Labor, $0.225 per hour.

Cost of manufacturing 1,233 lin. ft. of rail of the above description. Taken from the Report of the New York State Highway Commission of 1910.

Lumber	$ 32.46	$0.026 per lin. foot.
Steel	139.64	0.114 " " "
Cement	57.62	0.046 " " "
Gravel	10.00	0.008 " " "
Metal cores	77.00	0.063 " " "

Labor	...............231.83	....0.188	"	"	"
Miscellaneous	.... 5.35	....0.004	"	"	"
Total	...........$553.90	....0.449			

his data applies to small quantities; if manufactured on a e scale the cost should be reduced to about $0.30 per lin. ft. he cost of setting the above rail varied from $0.09 to $0.125 lin. ft: labor $0.225 per hour. This does not include haul- from the factory to the intended position on the road.

ble Gutter. Road 5,046, W. G. Harger, Engineer.

abor, $0.175 per hour. Foreman, $3.50 per day.

obbles averaged 6 in. in size; no sand cushion required, as .er was built in a sand cut. Gutter was laid by ordinary rers using paver's tools; tamped with a paving rammer, and top voids filled with No. 2 stone crushed on the job.

30 sq. yds. were laid at the following cost per sq. yd.:

bles, free	$0.000
ding ¼ cu. yds. of cobbles	0.030
ıling ¼ " " " ½ mile	0.024
ing and tamping	0.080
er. Cost of 0.05 cu. yds. No. 2 stone at crusher bin,	
pproximately	0.030
ıling 0.05 cu. yds. 1 mile	0.015
eading and brooming, 0.05 per cu. yd. No. 2 stone ...	0.010
Total	$0.189

PRICES OF VITRIFIED PIPE

he discounts vary, but if no quotations of current prices available the following list will serve for an approximate mate:

[1] Eastern List

Size	Discount
3" to 24"	........88%
24" and 30"	.....80%
33" and 36"	.....75%

t these discounts the net prices per foot in car-load lots f.o.b. ory are:

Size	Price	Size	Price
3"	$0.024	20"	$0.270
4"	0.030	21"	0.325
5"	0.036	22"	0.360
6"	0.048	24"	0.390
8"	0.066	27"	0.900
10"	0.096	30"	1.100
12"	0.120	33"	1.560
15"	0.162	36"	1.750
18"	0.227	—	—

[1] *Engineering News*, April 4, 1912.

TABLE 50.—SPEED OF WORK, VALUE OF PLANT, FORCE ACCOUNT. SUMMARY OF PLANTS AND FORCE ACCOUNTS

Road No.	Style of Road	Local or Imported Stone	Kind of Hauling	Weekly Force Account	Value of Plant	Speed of Work Miles per Month
1	16-ft. Bit. Mac. ..	Imported	Mechanical and teams	$1,000	$13,500	0.7
2	16 " " "	"	Mechanical	800	13,600	0.7
3	16 " " " .	"	Teams	900	8,000	0.5
4	16 " " " .	"	"	1,000	8,000	0.6
5	16 " " " .	"	"	—	4,500	0.4
6	16 " " " ..	" top (local bot.)	"	1,900	14,500	1.3
7	16 " " "	Local	Teams and Mechanical	600	12,000	0.5
8	16 " " " ..	"	Teams	1,000	9,000	0.5
9	16 " " " ..	"	"	600	9,000	0.6
10	16 " Water Mac .	"	"	1,600	10,000	1.2
11	16 " " " ..	"	"	1,000	10,500	0.8
12	16 " " " .	Imported	"	1,000	6,000	0.7
13	14 " " " ...	"	"	1,200	12,600	0.7
14	16 Resurfacing ...	"		500	5,000	1.5

Labor, $0.16 to $0.20 per hour. Average $0.175. Teams, $0.40 to $0.50 per hour. Average $0.45.

PLANT AND PAY-ROLL

le 50, page 252, shows in a convenient form the value ıts and the largest weekly force account of two months' ɔn on fourteen roads in New York State. From this and nformation it is reasonable to assume that a contractor has ɔ, outside of money on plant and materials, from $5,000 ›oo for the full length of time that the work is in progress, r short periods he may have as high as $15,000 or $20,000 :d.

rest, Depreciation, Repairs, etc. To the best of my ent the following estimates show about the amount of required on the different styles of construction noted. data are based on an outfit which would be capable of d of about 0.7 mile per month, or five miles in a season.

Adopted Value of Plant Items

Item	Value	Life	Annual Repairs
roller	$2700	20 yrs.	$70.00
roller	1800	20 "	40.00
on-engine	1200	8 "	100.00
:r	900		
or	200	8 "	400.00
ıd screen	500		
gasoline engine	250	8 "	50.00
ıgine and pump	200	5 "	50.00
t. of pipe	600	say 10 "	10.00
ıs	115	6 "	10.00
tools	150	1 "	—
	100	3 "	—
machine	200	5 "	10.00
:ttle	$125–200	—	[1] 10.00
scraper	70	5 "	10.00
scraper	6	5 "	—
roller used for hauling	2700	10 "	200.00
ıg traction-engine	2200	8 "	200.00

[1] Including new tank every three years.

6% Interest and Depreciation on Plant Items

Item	Interest	Depreciation
Roller	$162.00	$135.00
Traction-engine	72.00	150.00
Crusher	54.00	100.00
Elevator	12.00	30.00
Screen	3.00	50.00
Bin	30.00	40.00
Gasoline engine	15.00	30.00
Gasoline pump	12.00	40.00
6000 feet 1½" pipe	36.00	60.00
Wagons	6.00	20.00
Hand tools	9.00	150.00
Plows	6.00	30.00
Tar kettle	12.00	10.00
Concrete mixer	120.00	—
Brick roller	108.00	100.00
Wheel scrapers	5.00	15.00
Slush scrapers	—	—
Roller used for hauling	162.00	270.00
Hauling engine	132.00	300.00

Charge for bond ½% total contract.

PLANT FOR WATERBOUND MACADAM IMPORTED STONE

Elevator unloading plant, provided more than 2,000 cu. yds. of stone is to be unloaded.

Item	Interest	Depreciation	Repairs
Elevator	$12.00	$30.00	$50.00
Bin	30.00	40.00	50.00
5 H.P. gasoline engine	15.00	30.00	50.00
1 roller with broom and sprinkling attachment	162.00	135.00	70.00
6000 ft. 1½" pipe	36.00	60.00	10.00
Gasoline engine and pump	12.00	40.00	50.00
Hand tools	9.00	150.00	—
Plows	6.00	30.00	—
Road machine	12.00	40.00	10.00
2 wheel scrapers	5.00	15.00	10.00
2 slush scrapers	—	—	—
15 wagons	80.00	300.00	150.00
Totals one season's work 5 miles	$379.00	$870.00	$450.00
Total per mile	76.00	174.00	90.00

Force account money out: Allow six weeks out continually for length of job at ½% interest per month.

Allow $6,000 out, or $40.00 interest per mile on force account.

Bond charge: ¼ of 1% contract price; approximately $25.00 per mile. Insurance charge: $2.00 per $100.00 total force account, approximately $100.00 per mile.

Allow for moving plant on job, $500.00 lump sum.

Plant for Waterbound Macadam Local Stone

Item	Interest	Depreciation	Repairs
1 traction engine	$ 72.00	$150.00	$100.00
1 crusher and bin	100.00	220.00	400.00
1 steam drill and bits	10.00	50.00	80.00
1 small boiler for drill	12.00	30.00	20.00
Roller, pipe, gasoline engine and pump, hand tools, plows, road machine, scrapers and wagons as for imported stone plant. Total of these items	322.00	770.00	300.00
Total for season, 5 miles	$516.00	$1220.00	$900.00
Total per mile	103.00	245.00	180.00

Force account slightly larger on local stone roads. Approximately $7,000.00 out.

Interest on force account . . . . $50.00 per mile
Bond charge . . . . 20.00 " "
Insurance . . . . 120.00 " "

Moving plant on job, $500.00 lump sum.

Plant for Bituminous Macadam Imported Stone

Item	Interest	Depreciation	Repairs
Elevator unloading plant	$60.00	$100.00	$150.00
2 rollers	320.00	270.00	140.00
3 tar kettles	36.00	—	30.00
Hand tools, plows, road machine, scrapers and wagons as for waterbound macadam. Total of these items	112.00	535.00	170.00
Total for season, 5 miles	$528.00	$905.00	$490.00
Total per mile	106.00	181.00	98.00

Interest on force account . . . . $40.00 per mile
Bond charge . . . . 30.00 " "
Insurance . . . . 100.00 " "

Moving plant on job, $500.00 lump sum.

PLANT FOR BITUMINOUS MACADAM LOCAL STONE

Item	Interest	Depreciation	Repairs
1 traction engine	$72.00	$150.00	$100.00
1 crusher outfit	100.00	220.00	400.00
1 steam drill and bits	10.00	50.00	80.00
1 portable boiler for drill	12.00	30.00	20.00
Rollers, hand tools, plows, road machine, scrapers, wagons, and tar kettles as for imported stone. Total of these items	468.00	805.00	340.00
Total for the season, 5 miles	$662.00	$1255.00	$940.00
Total per mile	132.00	251.00	188.00

Interest on force account .... $50.00 per mile
Bond charge .... 25.00 " "
Insurance .... 120.00 " "

Moving plant on job, $500.00 lump sum.

FORMS FOR ESTIMATES

The following forms of estimate have proved very satisfactory. The item of 6% on materials is used to cover demurrage and interest on money tied up on freight and stone. The other items of profit are what we consider a reasonable return for the risk of such contract work. Mechanical hauling is not considered, because few contractors own plants that make it possible. The total item of interest, depreciation, repairs, and interest on force account money for the whole job is charged against top and bottom stone, as the construction quantities of the macadam will vary less from the estimated quantities than any other classes of work.

Standard Estimates. Figured on the basis of 20% profit on labor, 6% on materials, 6% on money invested, and an allowance made for depreciation on different plants, as previously given.

Labor at $0.175 per hour
Teams at $0.450 " "

Earth Excavation.

Class	Amount per Mile	Price per Cu. Yd.
Easy	5,000–10,000 cu. yds.	$0.40
Easy	3,000– 5,000 cu. yds.	0.45
Easy	1,500– 3,000 " "	0.50
Average	3,000– 5,000 " "	0.50
Average	1,500– 3,000 " "	0.60
Hard...........	3,000– 5,000 " "	0.60
Hard...........	1,500– 3,000 " "	0.70

Rock Excavation.

Large boulders (for which 10 cu. yds. a mile are allowed on all estimates) . . .$1.50 per cu. yd.

1. { Steam drillwork, limestone .... 1.25 " " "
   { " " " granite .... 1.50 " " "

2. { Hand " " limestone .... 2.00 " " "
   { " " " granite .... 2.00 " " "

1. Large quantities
2. Small quantities

Field Stone Sub-base.

A sub-base course 6 in. deep made of the usual size fence stone requires 1 cu. yd. loose for 1 cu. yd. rolled; 12 in. deep requires 1.25 cu. yds. loose.

Cost of cobbles per loose cu. yd.	$0.10	Multiply these items by 1.25 for 12-in. depth of sub-base.
Loading cobbles per loose cu. yd......	0.15	
Hauling cobbles 1 mile per loose cu. yd.	0.35	
Placing cobbles per loose cu. yd.	0.10	
Rolling cobbles per loose cu. yd.	0.05	
Filler (see below)..................	—	
Total	$ —	
20% profit	$ —	
Estimate	$ —	

Filler.

¼ cu. yd. per cu. yd. rolled sub-base.

Cost ¼ cu. yd. at pit or crusher	$ —
Loading ¼ cu. yd.	0.05
Hauling ¼ cu. yd. 1 mile	0.10
Spreading ¼ cu. yd.	0.04
Total	$ —

Sub-base Bottom Course.

Same relation of loose and rolled quantities as for sub-base.

Cost fence stone per loose cu. yd.	$0.10
Loading fence stone per loose cu. yd.	0.15
Hauling 1 mile per loose cu. yd.	0.35
Placing and sledging	0.20
Rolling	0.05
Filler (see below)	—
Total	$ —
20% profit	—
Estimate	—

Filler.

⅓ cu. yd. per cu. yd. rolled sub-base.

Cost ⅓ cu. yd. at pit or crusher	$ —
Loading	0.05
Hauling 0.33 cu. yd. filler per mile	0.10
Spreading and brooming	0.08
Total	$ —

Imported Bottom Stone Materials.

3″ course, 3,050[1] lbs. f.o.b. crusher	$ —
4″ " 3,150 " " "	—
6% profit	—
Total	$ —
Freight on stone to delivery point	—
Total, No. 1	$ —

Labor.

Unloading		
Under 2,000 cu. yds. (shoveling)	$0.15	per cu. yd.
Over 2,000 cu. yds. (elevator)	0.10	" " "
Hauling (Teams)		
Bad conditions	0.35	" " "
Average conditions	0.30	" " "
Good conditions	0.25	" " "
Mechanical hauling	0.15	" " "
Spreading		
5½ in. loose depth	0.06	" " "
4 in. loose depth	0.08	" " "
Rolling	0.05	" " "

At this point total up and add 30% of the total to change the estimate from loose to rolled measure.

Filler (see below)	
Labor, total	$ —
20% profit	—
Total, No. 2	$ —

[1] These weights are for limestone. See pages 230, 234.

ller.

Cost of 0.35 cu. yd. at pit or crusher	$ —
Loading 0.35 " "	0.05
Hauling 0.35 " " 1 mile @ $0.35 per yd. mile	0.12
Spreading and brooming 0.35 cu. yd.	0.07
Filler, Total	$ —

ummary.

Total No. 1	$ —
Total No. 2	$ —
Interest and depreciation	$ —
Estimate	$ —

mported Top Stone Waterbound Macadam Materials.

[1] 4,450 lbs. stone f.o.b.	$ —
6% profit	$ —
Total	$ —
Freight on stone to delivery point	$ —
Total No. 1	$ —

abor.

Unloading (same as bottom)	$ —
Hauling (same as bottom)	$ —
Spreading	0.08
Rolling	0.04
Puddling	0.06
Total, loose measure	$ —
Add 30%	$ —
Total rolled measure	$ —
Screenings. (See below)	
Total	$ —
20% profit	—
Total No. 2	$ —

Screenings.

[2] Unloading 0.5 cu. yd.	$0.07
Hauling 0.5 " " 1 mile	0.15
Spreading 0.5 " " by cross dump wagons	0.03
" 0.5 " " " hand	0.07
Total	$ —

Summary.

Total No. 1	$ —
Total No. 2	—
Interest, depreciation, etc.	—
Estimate	$ —

[1] These weights are for limestone. See pages 230, 234.
[2] *Screenings* are usually unloaded by hand.

IMPORTED TOP STONE BITUMINOUS MACADAM PENETRATION METHOD

Materials.

2" course, 4,350 lbs. stone and screenings, f.o.b. crusher ..	$ —
3" " 4,050 " " " " " " ...	—
gal. bituminous binder, f.o.b. plant	—
6% profit	—
Total	$ —
Freight on materials to delivery point..................	—
Total No. 1	$ —

Labor.

No. 3 stone.

Unloading 1 cu. yd. (same as given)	$ —
Hauling 1 cu. yd. " " "	—
Spreading 1 cu. yd. " " "	—
Rolling 1 cu. yd.	0.09
Total	$ —
Add 20% for 2" course, 30% for 3" course	—
Total No. 2	$ —

No. 1A, No. 2, and Bitumen.

Unloading 0.6 cu. yd. for 2" course (same as given)	$ —
" 0.45 " " " 3" " " " "	—
Hauling at the rate of $0.30 per yd. per mile............	—
Hauling bitumen at rate of $0.002 per gal. per mile	—
Spreading and brooming No. 1A and No. 2 at rate of $0.30 per cu. yd.	—
Manipulation of heating and spreading bitumen at $0.015 per gal..	—
Total No. 3	$ —
Total No. 2	—
Total	$ —
Add 20% profit	—
Total No. 4	$ —

Summary.

Total No. 1	$ —
Total No. 4	—
Interest, depreciation, etc.	—
Estimate	$ —

Local Stone Macadam.

Field stone.

1 cu. yd. field stone = 1 cu. yd. crushed.
1.8 cu. yds. field stone = 1 cu. yd. No. 3 and No. 4 rolled.

Cost of field stone	$0.10 per cu. yd.
Blasting or sledging, per cu. yd. actually blasted *or sledged*	0.40 " " "

Loading field stone	0.15	per cu. yd.
Hauling field stone 1 mile	0.35	" " "
Crushing		" " "
Sandstone (soft)	0.10	" " "
Limestone	0.15	" " "
Granite and trap rock	0.20	" " "
Total cost in bins (loose including Nos. 1, 2, 3, and 4 stone)	$ —	" " "

Quarried Stone.

Limestone, quarrying, small quarries	$0.50	" " "
Conglomerate, " " "	0.75	" " "
Trap, " " "	0.65	" " "
Crushing (same as above)	—	" " "
Total cost in bins	$ —	" " "

The crushing does not include repairs to crusher.
The crushing is taken from previously given data.
The item of quarrying includes delivery to crusher.

Estimate of Bottom Stone.

Cost in bins	$ —
Loading, per cu. yd.	0.01
Haul (same as bottom)	—
Spread (same as bottom)	—
Rolling (same as bottom)	—
Total (loose measure)	$ —
Add 30%	—
Total rolled measure	$ —
Filler (same as bottom)	—
20% profit	—
Total, No. 1	$ —
Interest and depreciation	—
Estimate	$ —

Local Top Stone.

Cost in bins	$ —
Manipulation same as for imported stone	—
Total	$ —
20% profit	—
Total No. 1	$ —
Interest and depreciation	—
Estimate	$ —

Imported No. 2 Stone, Estimated Loose **Material.**

2,400 lbs. stone	$ —
6% profit	—
Total No. 1	$ —

Unloading (same as bottom)	—
Haul (same as bottom)	—
Spreading	0.10
Total	$ —
20% profit	—
Total No. 2	$ —

Total No. 1	$	—
Total No. 2		—
Estimate	$	—

Local No. 2 Stone.

Cost per cu. yd. in bins	$	—
Haul same as above		—
Spreading same as above		—
Total	$	—
20% profit		—
Estimate	$	—

The following is an example of the method of using these standa forms.

Estimate for Local Fence Stone Bottom Course

Assume that stone will cost $0.10 per cu. yd. in the fences.
" ½ mile average haul to crusher.
" 20% of the stone has to be sledged or blasted.
" ¾ of a mile average haul from the crusher.
" that filler costs $0.15 per cu. yd. in the pit.
" average haul of ¼ mile for filler.
" that the interest and depreciation charge for the tot job, say 4 miles, is distributed over 6,000 cu. yds. of macada

Use Standard form for Local Bottom Stone, given on page 261.

Cost 1 cu. yd. field stone	$0.10
Blasting and sledging ⅕ cu. yd. stone	0.08
Loading 1 cu. yd. field stone	0.15
Hauling 1 cu. yd. field stone ½ mile	0.18
Crushing 1 cu. yd. (Mixed granite and sandstone)	0.15
1 cu. yd. Total cost in bin	$0.66

Cost 1 cu. yd. crushed stone in bins	$0.66
Loading on wagons	0.01
Haul to road, average conditions, ¾ of a mile ...	0.22
Spreading 5⅓" loose	0.06
Rolling	0.05
Total	$1.00

Add 30%	.30
Per. cu. yd. rolled measure	$1.30
Filler (see below)	0.31
Labor, total	$1.61
Add 20% profit	0.32
Total, No. 1	$1.93
Interest, depreciation, etc. (see below)	.56
;stimate per cu. yd. rolled in place	$2.49

$2.50.

'iller. As mentioned on page 240, the screenings produced in shing bottom only, as in this case, will amount only to 50% of required filler, therefore two estimates must be made for filler pelow:

Screenings for Filler.

st of 0.35 cu. yds. screenings	in bin @ $0.66 per cu. yd.	$0.230
ıding 0.35 " " "	from bin	0.003
uling 0.35 " " "	$\frac{3}{4}$ of a mile	0.077
eading and brooming 0.35 cu. yds.		0.070
Total		$0.380

Sand Filler.

st of sand in pit 0.35 cu. yds.	$0.052
ıding 0.35 cu. yds.	0.050
uling 0.35 " " $\frac{1}{4}$ mile (short-haul figures)	0.060
eading and brooming 0.35 cu. yds.	0.070
Total	$0.232

ıverage these costs as the screenings must be utilized to use up total output of the crusher. Average filler $0.31.

nterest, Depreciation, etc.

'rom page 255, using value adopted for, say, waterbound macadam ds, the following charge for a 4-mile road is figured:

Interest on plant	4×103.00	$412.00
Depreciation on plant	4×245.00	980.00
Repairs on plant	4×180.00	720.00
Interest on pay-roll	4× 50.00	200.00
Bond charge	4× 20.00	80.00
Insurance	4×120.00	480.00
Moving plant on job		500.00
Total		$3,372.00

›e spread over 6,000 cu. yds. of macadam.

$$\frac{3,372}{6.000} = 0.56 \text{ cents}$$

The cost of an improved highway generally depends on the item of top and bottom stone in place complete. Many of the minor items have standard prices. Such items as cast-iron pipe, the various sizes of tile, pipe railing, mesh reinforcement steel, etc., will hardly vary in price throughout the Eastern States. A table of these standard prices as used by the New York State Highway Commission is given below.

It will be noted that all of these items have little bearing on the total cost, and that the items of Earth Excavation, Sub-base, or Sub-base Bottom Course, Macadam Bottom and Top Course, Concrete Foundation, Brick Pavement, etc., which of necessity are not standard in price, determine whether or not the road is to be expensive.

Unit Prices Minor Items

Overhaul on excavation	$ 0.01	per yd. sta.
Third-class masonry cement joints	6.00	per cu. yd.
Second-class concrete	9.00	" " "
Third-class concrete (stone)	7.00	" " "
" " " (gravel)	5.50	" " "
Pointing old masonry	0.75	" sq. "
Riprap	1.50	" cu. "
Paving cement joints	1.50	" sq. "
Cobble gutter	0.50	" " "
Expanded metal	0.08	" " ft.
Guard-rail	0.30	" lin. ft.
2" pipe rail	1.50	" " "
Concrete guard-rail	1.00	" " "
Cast-iron pipe in place	35.00	" ton
6" V. T. P. in place	0.30	" lin. ft.
12" V. T. P. " "	0.60	" " "
15" V. T. P. " "	0.90	" " "
18" V. T. P. " "	1.10	" " "
24" V. T. P. " "	2.00	" " "
Relaying old pipe	0.10	" " "
4" farm tile under drain in place	0.10	" " "
Steel in place	0.05	" lb.
Oak timber in place	50.00	" M.B.M.
Hemlock timber in place	40.00	" M.B.M.
Danger signs	2.00	each
Guide-board posts	6.00	"
Highway No. signs	1.00	"
Guide signs per letter	0.15	"

The item of Earth Excavation as shown in Table 36 may vary between 40c and 65c. In extreme cases where material is difficult to handle, it may be estimated still higher. A particular instance of costly excavation where 70c was estimated occurs on a road near the Lackawanna Steel Plant at Buffalo. This road had been filled with slag from time to time.

In the remaining variable items the length of haul is a governing *factor and three* actual conditions of determining the average haul *are given here before* proceeding farther with the estimate data.

The following cases 1, 2, and 3 show also the present method of estimating where interest and depreciation are not directly considered.

Case I

The simplest possible conditions. Perry Village County Highway, Wyoming County, N.Y. Imported stone, delivery at middle of road — coal trestle available for unloading — no dead haul to road. Road 16 feet wide throughout.

Railroad at Station 60 Station 0+00 = beginning of contract
106+23 = end of contract

For ease of computation, say stone runs 10 yds. to mile.

Station 0 + 00 to 60

1.1 miles average .55 miles .55 miles × 11 yds. = 6.05 yd. miles

Station 60 + 00 to 106 + 23

.87 miles average .44 miles .44 miles × 8.7 yds. = 3.83 yd. miles

Total yds. 19.7 9.88 yd. miles Total

$$\frac{9.88 \text{ yd. miles}}{19.7 \text{ yds.}} = 0.50 \text{ miles average haul}$$

Completion of Perry Village Estimate.

Stone from Rock Glen Quarries	Stone	$0.65 per ton f.o.b.
Cu. yd = 2400 lbs.	Freight	.40 " " "
	Sub-base Stone	.50 " " "

	Bottom	Top	Screenings	Sub-base
Stone	.78	.78	.78	.60
Unloading	.15	.15	.15	.15
Average haul ½ mi. at .35	.175	.175	.175	.175
Manipulation	.30	.25	.20	.20
			1.305	
Consolidation (plus ⅓).	.468	.451	.4 + ⅓	.22
			.5220	
Filler (½ cu. yd. sand at $1.00)	.50	Screenings .522	Sand	.50
Profit (20%)	.474	.465		.369
Freight (40 + .08 + .16)	.64	(40+.08+.16+192) .832	(40+08+.096)	.576
6% interest on freight to cover demurrage, etc.	.038	.05		.034
Manipulation of Bituminous Material		.60		
	$3.525	$4.275		$2.824
	Use $3.55	Use $4.30		Use $2.80

Case II

The Walker-Lake Ontario Road, Monroe County, N.Y. Road *extends from Station* 0 + 00 to Station 197 + 45.

Local stone — mostly fences. Because of location of stone as determined by engineer's inspection, it was determined to make three set-ups of crusher, at Station 40, 104 + 50 and at Station 157.

The hauls from stone piles to these crushing points were figured in the regular manner. From the crusher to road, the hauls were arranged,

From Station 40 — haul stone	0 + 00 to 77 + 00
" " 104 + 50 haul stone	77 + 00 " 130 + 00
" " 157 " "	130 + 00 " 197 + 45

Care was taken to see that enough stone was available near each crushing point to furnish macadam between stations supplied from that set-up.

The widths of road were as follows:

0 + 00 to 40 + 00 — 12′ wide
40 + 00 " 66 + 60 — 16′ wide
66 + 60 " 129 + 50 — 14′ "
129 + 50 " 197 + 45 — 12′ "

Use 10 yds. per mile for 12′ road
proportionally 11.7 yds. mile for 14′ road
" 13.3 " " " 16′ "

Haul on road from Station 40 + 00

12′ wide 0 + 00 to 40 + 00
0.76 miles average .38 .38 miles × 7.6 yds. = 2.89 yd. miles
16′ wide 40 + 00 to 66 + 60
.50 miles average .25 .25 miles × 6.6 yds. = 1.65 yd. miles
14′ wide 66 + 60 to 77 + 00
.20 miles average .1
plus dead haul .5
.6 .6 miles × 2.3 yds. = 1.38
16.5 5.92 yd. miles

Haul on road from Station 104 + 50

14′ wide Station 77 + 00 to 129 + 50 (say 130)
77 + 00 to 104 + 50
.52 miles average .26 .26 miles × 6.1 yds. = 1.59 yd. miles
104 + 50 to 130
.48 miles average .24 .24 miles × 5.6 yds. = 1.34 yd. miles
11.7 yds. 2.93 yd. miles

Haul on road from Station 157

12′ wide Station 129 + 50 (say 130) to 197 + 45
130 to 157
.51 miles average .26 .26 miles × 5.1 yds. = 1.33 yd. miles
157 to 197 + 45
.76 miles average .38 .38 miles × 7.6 yds. = 2.89 yd. miles
12.7 yds. 4.22 yd. miles

verage haul for entire road

n Station	40	16.5 yds.	5.92 yd. miles
" "	104 + 50	11.7 "	2.93 " "
" "	157	12.7 "	4.22 " "
		40.9	13.07

13.07 ÷ 40.9 = .32 miles
say .3 miles average haul

Sub-base Bottom Course

ıe	$ .15
lging, blasting, and sorting 30% of stone at .35 per yd.	.105
ding into wagons	.15
ıl to crusher at Stations 40, 104 + 50 and 157. One ıile at .35	.35
ıl on road. 3 mile at .35	.105
nipulation	.20
ısolidation (plus ⅓)	.212
ɜr (½ cu. yd. sand at .80)	.40
fit (20%)	.334
	$2.006

Use $2.00

Local Stone Top Course — Bituminous Binder

	Top Course	Screenings
ıe	.15	.15
lging, blasting, and sorting 60% of :one at .35	.21	.21
ding into wagons	.15	15
ıl to Crusher at Stations 40, 104 + 50 nd 157. 1.1 miles at .35	.385	.385
shing	.35	.35
ıl on road .30 miles at .35	.105	.105
nipulation	.20	.20
ısolidation (plus ⅓)	.517	1.55
		× .4
er (.4 cu. yd. of screenings)	.620	.620
fit (20 %)	.537	
nipulation Bituminous Material	.60	
	$3.824	

Use $3.85

Case III

'he Obi-Cuba Highway, #965, Allegany County, N. Y.
; miles long.

'rom a field inspection of this road, it was found that stone was ilable at both ends of road, but not in the middle. An ample ply of good gravel was found in the middle section, and it was ɜrmined to build a concrete base with bituminous top, this type 'oad *being the only* one which could be built using local material.

The hauls and freight charges on imported material would make the cost prohibitive.

The road was divided into three sections as follows:

Station 0 + 00 to 330	local field stone	concrete
Station 330 + 00 " 460	" gravel	"
Station 460 + 00 " 524 + 14	" quarry stone	"

Haul on stone 0 + 00 to 330. Crusher at 146, 220, and 285. These crusher set-ups were determined upon more by reason of nearness of stone supply and grade of haul than to equalize the hauling distance. The haul to the crusher was figured for the separate sources of supply and found to average 1½ miles.

Haul from crusher on road, Station 146 to Station 0 + 00

(12′ wide use 10 yds. per mile) 2.76 miles, average 1.38 miles.

Station 146 to 170	1.38 miles	× 27.6 yds.	=	38.09 yd. mi.
0.5 miles, average .25 miles	.25 "	× 5 "	=	1.25 " "
Station 220 to 170				
1.0 miles, average 0.5 miles	.5 "	× 10 "	=	5.0 " "
Station 220 to 245				
0.5 miles, average .25 miles	.25 "	× 5 "	=	1.25 " "
Station 285 to 245				
0.8 miles, average 0.4 miles	.4 "	× 8 "	=	3.2 " "
Station 285 to 330				
0.86 miles, average .43 miles	.43 "	× 8.6 "	=	3.7 " "
Total for 1st section		64.2 yds.		52.49 yd. mi.

52.49 ÷ 64.2 = 0.82 mile, average haul for 1st section.

Haul from gravel pit to road. Station 330 to 460.

Bank station 385 at side of road — no dead haul great enough to be figured.

Station 385 to 330				
1.1 miles, average haul .55 miles	.55 miles	× 11 yds.	=	6.05 yd. miles
Station 385 to 460				
1.4 miles average haul .7 miles	.7 "	× 14 "	=	9.8 " "
	Total	25 yds.		15.85 yd. miles

15.85 ÷ 25 = .63 miles Say .65 average haul

Haul from quarry in Village of Cuba ¾ mile from end of road.

Station 460 to 524 + 14
Station 460 " 500 14′ wide (use 11.7 yds. per mile)
Station 500 " 524 + 14 16′ wide (use 13.3 yds. per mile)

Station 460 to 500	
0.8 miles, average	.4 mi.
Station 524 + 14 to 500 dead haul	.5 "
Quarry to 524 + 14 " "	.75 "
	1.65 "

1.65 miles × 9.36 yds. = 15.44 yd. mi.

Station 500 to 524 + 14
0.5 miles, average haul .25 mile
Quarry to 524+14 dead haul .75 mi. 1 mile × 13.3 yds. = 13.3 yd. mi.
1.00 mi. Total 22.66 28.74 " "

18.74 ÷ 22.66 = 1.27 Say 1.3 miles average haul

Haul on Sand — *Pits at Stations 26 and 385*

Station 26 to 0 + 00					
5 miles, average	.25 mi.	.25 miles	× 5 yds.	=	1.25 yd. mi.
Station 26 to 330					
5.76 miles, average	2.88 mi.	2.88 "	× 57.6 "	=	165.89 " "
Station 385 to 330					
1.04 miles, average	.52 mi.	.52 "	× 10.4 "	=	5.4 " "
Station 385 to 460					
1.4 miles, average .7 mi.		.7 "	× 14.0 "	=	9.8 " "
Station 460 to 500					
0.8 miles, average	.4 mi.				
385 to 460 dead haul	1.4 mi.				
Total	1.8 "	1.8 "	× 9.36 "	=	16.8 " "
Station 500 to 524 + 14					
0.5 miles, average	.25 mi.				
460 to 500 dead haul	.8 mi.				
385 to 460 " "	1.4 mi.				
Total	2.45 mi.	2.45 "	× 6.65 yds.	=	16.3 " "
			103.01		215.44

215.44 ÷ 103.01 = 2.1 miles average haul.

Haul on Cement

Cement delivered at Cuba and Portville.

Station 0 + 00 to 160		Say 10 bbls. to mile
3 miles, average	1.5 mi.	7.5 miles × 30 bbls. = 225 bbl. mi.
dead haul, Portville	6.0 mi.	
to 0 + 00	7.5 mi.	
Station 160 to 460		
5.68 miles, average	2.84 mi.	
460 to 524 + 14 dead	1.3 mi.	
Penn. R.R. to 524 + 14	.2 mi.	
	4.34 mi.	
		4.34 mi. × 56.8 bbls. = 246.5 bbl. mi.
Station 460 to 500.		
.8 miles, average	0.4 mi.	
500 to 524 + 14 dead	.5 mi.	
Penn. R.R. to 524 + 14	.2 mi.	
	1.1 mi.	
		1.1 mi. × 9.36 bbls. = 10.3 bbl. mi.
Station 500 to 524 + 14		
.5 average	.25 mi.	
Penn. R.R. to 524 + 14	.2 mi.	.45 mi. × 6.65 bbls. = 3.0 bbl. mi.
	.45	102.81 — 484.8 bbl. mi.

484.8 ÷ 102.81 = 4.7 miles, average haul.

Having the haul figured for stone, gravel, cement, and sand, it was decided to obtain a composite price for the aggregate of the concrete instead of presenting an estimate with three prices for concrete foundation. This was done as follows:

Field Stone.

Stone	$.10 yd. royalty	
Blasting	.35 "	
Loading	.15 "	
Haul to crusher 1.5 @ 40c	.60 "	40c. yd mile used as haul
[1] Crushing	.30 "	was off steep hills and
Haul to road .8 mi. @ 35c.	.28 "	hard grades
	$1.78 yd.	

Gravel.

Gravel (royalty)	$.50
Stripping	.05
Loading (by hand)	.15
Haul to Station 385, 0.1 mile @ 35c.	.03
Haul on road, .65 miles @ 35c.	.23
	$.96

Stone at Cuba Quarry.

This stone bought from quarry owner at flat rate of 75c. in bins:

Stone	$.75	
Haul 1.3 @ 35c.	.455	
	$1.205	Say $1.21

Sta. 0+00 to 330	= 6.25 miles	@ 10 yds.	= 62.5	× $1.78	= $111.25
330 " 460	= 2.46 "	" 10 "	= 24.6	× .96	= 23.62
460 " 500	= .8 "	" 11.7 "	= 9.36	× 1.21	= 11.33
500 to 524+14	= .5 "	" 13.3 "	= 6.65	× 1.21	= 8.05
			103.11		$154.25

$154.25 ÷ 103.11 = $1.49 composite price

Sand

Sand (screened)	$1.00 yd. royalty	
Loading	.10 "	
Haul to road 0.1 @ 40c.	.04 "	40c. used because of
Haul on road 2.1 miles @ 35c.	.735	steep hard grade
	$1.875	Say $1.88

Cement

Delivered at Cuba or Portville	$1.05 per bbl.
Haul .188 tons × 4.7 miles × .29 per ton mile	.25 " "
	$1.30

Concrete

Inasmuch as gravel must be screened and sharp sand supplied, the proportions for stone concrete, ratio 1 — 2½ — 5, were used in place of standard gravel proportions. This is Fuller's rule for proportions of cement, stone, etc., for one cubic yard of concrete. A table of these ratios for different mixtures is found on page 248.

Stone	$1.49 × .92	= $1.3708
Sand	1.88 × .46	= .8648
Cement	1.30 × 1.21	= 1.573
		$3.8086

[1] *This item is higher than noted in the previously given cost data, as this estimate is made according to the N. Y. S. method, which does not consider interest and depreciation as a separate item.*

Mixing	$ .40
Spreading	.20
Profit 20%	.8817
	$5.2903

Say $5.30 per cu. yd.

NOTE: — This method of estimating does not consider deprecia-
on directly. See other method of estimating following.

The method of estimating the top course for a Concrete Bitumin-
is Top road does not vary from an ordinary bituminous top course,
cept that under the present New York State specifications the
urse is figured for loose measure. Therefore the items for con-
lidation and filler would be omitted.

rick Cost Data on Country Roads.

The cost of brick pavements on country roads differs somewhat
om similar work on city streets. There is not much data avail-
ble for this class of work, but through the courtesy of Mr. Wm. C.
erkins, First Assistant Engineer, New York State Department of
ighways, the author is able to give some unusually reliable data
otained from fifteen miles of brick paving averaging 14 ft. wide,
uilt near Buffalo, N.Y., in 1910. Mr. Perkins' method of estimating,
s given on page 275, assumes that 20% profit on both materials and
bor will take care of the plant and pay-roll charges and give a reason-
ble profit. The method of estimating is different from that given
n macadam roads. His results are good.

Excavation. Where brick pavement is built on an ordinary unim-
roved country road, the excavation is of the same class and will
st the same as given for macadam roads.

Where pavements are built over macadam roads and the old sur-
ice must be cut into two or three inches and reshaped, the excava-
on is much more expensive. For this class of work see page 278
carifying and reshaping).

Labor Manipulation for Different Items of Brick Pavement Laid During 1910, in the Buffalo Residency.

These items figured from force accounts kept by the different
ngineers in charge of roads.

Labor averaged $0.175 per hour.

Concrete Base, 5" thick (exclusive of edging).

Machine-mixing, laying same in place, including labor of tamping, etc.

Road No. 2-R, Buffalo-Hamburg	$0.0853	per sq. yd.	
" " 128, Buffalo-Aurora	0.0991	" " "	(gravel concrete)
" " 863, Blasdell Village	0.1228	" " "	
" " 87, Main Street, Sec. 2.	0.1129	" " "	(3" base)
" " 862, Hamburg Village	0.0655	" " "	(28' and 30' wide)

The excessive cost on Blasdell Village due to a poor concrete
nixer (gasoline) which was constantly breaking down.

On Main Street, Sec. 2, poor organization and too high price men; also, lack of water, causing delays.

On Hamburg Village low price due to width of base 28′ and 30′ allowing work to progress faster.

On Road No. 69, Main Street, Sec. 1, edging and base wer laid in one operation; gasoline mixer; plenty of water; cement $1.12; sand $1.40; labor, $1.90 per day; stone, $1.12 per cu. yd. base 3″ thick; 8″ edgings; cost in place, including edging $4.69 per cu. yd., or $0.506 per sq. yd., or $0.886 per lin. ft. of road.

Assumption. If we assume, $0.09 per sq. yd. as an average cos for 16′ road (exclusive of edging) the manipulation would b $0.648 per cu. yd.

If we assume $0.0655 per sq. yd. for street work (Hambur Village) the manipulation would be $0.472 per cu. yd.

Concrete Edging. 8″ thick.

Hand-mixed; placing same, including erecting of forms, an removing same; tamping, placing steel, and all labor necessary

Road No. 2-R, Buffalo-Hamburg,	$0.0730	per lin. ft. of edging
	0.0821	" sq. yd. of pavement (Road 16′ wide)
Road No. 128, Buffalo-Aurora,	0.0555	" lin. ft. of 5″ edging
	0.0713	" sq. yd. pavement (Road 14′ wide)
Road No. 863, Blasdell Village,	0.0826	" lin. ft. edging
	0.0929	" sq. yd. pavement (Road 16′ wide)
Road No. 87, Main Street, Sec. 2,	0.0748	" lin. ft. edging
	0.0842	" sq. yd. pavement (Road 16′ wide)

On Road No. 862, Hamburg Village, concrete curb 6″ t 10″ bottom, 15″ deep; hand-mixed, exposed curbing, all la including erection and removal of forms, $0.1294 per lin. ft.

Assumptions. If we assume $0.082 per sq. yd. of pavin cost of edging and $0.09 per sq. yd. cost of base, the total per sq. yd., 16′ road (including edging) would be $0.172 sq. yd., or the manipulation would be $1.238 per cu. yd.

If we assume $0.073 per lin. ft. of 8″ edging 10½″ deep manipulation would be $3.379 per cu. yd. of the edging in (This high cost due to forms, etc., and the small amount o crete per lin. ft.)

Sand Cushion.

Spreading sand, rolling, and making bed ready for work

Road No. 2-R,	Buffalo-Hamburg,	$0.0102	per sq. yd.
Road No. 128,	Buffalo-Aurora,	0.0082	" " "
Road No. 863,	Blasdell Village,	0.0187	" " "
Road No. 87,	Main St., Sec. 2,	0.0151	" " "
Road No. 862,	Hamburg Village,	0.0160	" " " (28′

On Main Street, Sec. 1, Road No. 69; sand, $1.4 $1.90; cost per sq. yd. 2″ thick, $0.0838, including mat

Assumption. From the above I would assume $0.013 per sq. yd. as cost of preparing sand cushion.

Brick Pavement.

Laying brick, including all labor of handling from the piles, removing all culls, and the rolling of the brick.

Road No. 2–R,	Buffalo-Hamburg,	$0.0611	per sq. yd.
Road No. 128,	Buffalo-Aurora,	0.0544	" " "
Road No. 863,	Blasdell Village,	0.0969	" " "
Road No. 87,	Main St., Sec. 2,	0.0965	" " "
Road No. 862,	Hamburg Village,	0.0700	" " " (28′ and 30′ wide)
Road No. 69,	Main St., Sec. 1,	0.0983	" " "

Assumption.

I consider Blasdell and Main Street, Sec. 1 and Sec. 2, too high and the engineer claims that the force was cut up and wasted time.

I would assume $0.070 per sq. yd. as cost of laying brick, etc.

Grouting.

Necessary grouting to obtain flush joints, scoop method, including the placing of the protecting sand covering.

Road No. 2–R,	Buffalo-Hamburg,	$0.0219	per sq. yd.
Road No. 128,	Buffalo-Aurora,	0.0211	" " "
Road No. 863,	Blasdell Village,	0.0322	" " "
Road No. 87,	Main St., Sec. 2,	0.0321	" " "
Road No. 69,	Main St., Sec. 1,	0.0285	" " "
Road No. 862,	Hamburg Village,	0.0273	" " " (28 and 30′ wide)

On Main St., Sec. 1, Road No. 69; sand, $1.40; cement, $1.12; labor, $1.90; actual cost $0.0848 per sq. yd., including materials.

Assumption.

From the above I would assume $0.028 per sq. yd., as the cost of applying grout.

Expansion Joints.

Removing strips, cleaning joints, and pouring tar.

Road No. 2–R,	Buffalo-Hamburg,	$0.0067	per lin. ft. of joint
		0.0076	" sq. yd. pavement (Road 16′ wide)
Road No. 128,	Buffalo-Aurora,	$0.0057	per lin. ft. of joint
		0.0073	" sq. yd. pavement (Road 14′ wide)
Road No. 863,	Blasdell Village,	$0.0115	per lin. ft. of joint
		0.0129	" sq. yd. pavement (Road 16′ wide)

On Main Street, Sec. 1, Road No. 69, the expansion joints cost $0.0296 per lin. ft., or $0.033 per sq. yd. (Road 16′ wide), including material, labor, etc.

Assumption.

From the above I would assume $0.0075 per sq. yd. as the cost of expansion joints.

Unloading.

Data for unloading not reliable.

Road No. 2–R Buffalo-Hamburg	$0.014 per sq. yd.
Road No. 863, Hamburg Village	Contract taken for $1.50 per 1,000 brick; unloaded, haul ¼ mile, and pile; this would be $0.06 per sq. yd.
Road, No. 69, Main St., Sec. 1	$0.019 per sq. yd.

Assumption.

I would assume $0.028 per sq. yd. as on and off.

Hauling.

No reliable data.

If we allow 600 brick per load, $5 per day for teams, 10 loads per day, haul 1 mile costs $0.034 per sq. yd.

Summary, Labor Cost of Brick Pavement.

MANIPULATION OF CONCRETE

Pavement 16′ wide; edging 8″ × 10½″.

Concrete base	$0.09	per sq. yd.	$0.648	per cu. yd.
" edge	0.082	" " "	3.378	" " "
Concrete base and edging	$0.172	" " "	1.238	" " "

BRICK WORK LABOR

Preparing sand cushion	$0.0130	per sq. yd.
Laying brick	0.0700	" " "
Grouting	0.0280	" " "
Expansion joints	0.0075	" " "
On and off	0.0280	" " "
Haul one mile	0.0340	" " "
Cost of labor	$0.1805	" " "

Useful Data for Brick Roads.

6″ × 10½″ edging per lin. ft. of edging	0.016203	cu. yd.
8″ × 10½″ " " " " "	0.021605	" "
5″ × 16′ concrete foundation per lin. ft. 16′ road	0.24691	" "
2″ sand cushion loose per sq. yd.	0.0555	" "

1 barrel of cement will grout 36 sq. yds. of pavement.

1 barrel of paving pitch will fill 130 lin. ft. of joints 1″ wide.

Amount of Grout Required for Stone Block Paving.

For blocks similar to Medina sandstone blocks, running about 26 to the sq. yd., Gillette states that 0.6 cu. ft. of joint filler are *required per sq.* yd. of pavement with joints averaging ½″ wide. *Second quality* blocks with wider joints require proportionally *more.*

STANDARD ESTIMATE, BRICK SURFACING, EXCLUSIVE OF FOUNDATION

Materials.

	Per Sq. Yd.
Cost of brick, f.o.b. unloading point	$
" " sand for sand cushion, on job	
" " " " grout, on job	
" " cement for grout, on job	
" " paving pitch for expansion joints, on job	

Labor and Teaming.

Unloading brick and piling along road	$0.035
Hauling brick per mile	0.040
Preparing sand cushion	0.020
Laying brick	0.070
Grouting	0.028
Expansion joints	0.007
Total	$ —
Add 20% profit	—
Estimate	$ —

SAMPLE — STANDARD ESTIMATE, BRICK PAVEMENT — WM. C. PERKINS

Brick: $22.50 per 1,000 f.o.b. cars at Road siding, bricks lay 40 to the sq. yd.
Labor, $0.175 per hour, 10 hours.
Sand, 1.00 per cu. yd. on cars at siding.
Stone, 1.25 per cu. yd. on cars at siding.
Cement, 1.30 per bbl. delivered on work.

Sand:

f.o.b. cars	$1.00
Unloading	.15
Haul 1 mile @ $0.30	.30
Cost cu. yd. sand	$1.45

Stone:

f.o.b. cars	$1.25
Unloading	.15
Haul 1 mile @ $0.30	.30
Cost cu. yd. stone	$1.70

Concrete: 1 – 2½ – 5.

Use any standard mixing tables, stone 1" and under, dust screened out.

Cement, 1.19 bbls.	× $1.30	= $1.55
Sand, 0.46 cu. yds.	× 1.45	= 0.67
Stone, 0.91 " "	× 1.70	= 1.55
Manipulation		= 0.50
		$4.27
20 % profit		.85
Total		$5.12

The manipulation is based on machine-mixing and is for base alone laid 5″ thick. The concrete edging is estimated separately and runs from $0.13 to $0.15 per lin. ft.

Material per Square Yard

Brick f.o.b. cars	$0.900	
Sand cushion and cover	0.080	
Grout (sand and cement)	0.042	
Material expansion joint	0.008	
		$1.030

Labor per Square Yard

Unloading and piling	$0.035	
Haul 1 mile	0.040	
Laying and rolling	0.070	
Making sand cushion	0.020	
Grouting	0.028	
Expansion joints	0.007	
Culling, replacing, etc	0.005	0.205
		$1.235
20 % profit		.247
Total		$1.482

Therefore, standard 16′ road is estimated to cost, per square yard (exclusive of edging):

Concrete base	$0.711	
Brick	1.482	
Total	$2.193	per sq. yd.
Say,	$2.20	per sq. yd.

In the above estimate I have allowed 20% profit on material and freight. I do this so as to cover all interest charges, incidentals, contingencies, etc. I consider this one of the fairest ways to take care of all general expenses.

MAINTENANCE AND REPAIR COSTS

Cold Oiling. The following data is furnished by Mr. Frank Bristow, Supt. of Repairs, Division No. 5, New York State Department of Highways. The work was done in 1910. Labor averaged $0.20 per hour; teams, $0.50 per hour.

Oiling. Actual Cost Data. No. 6 stock or 65% asphaltic base oils applied cold by Studebaker Oiler upon macadam road which had been swept by horse sweeper, oil being broomed by hand where necessary and then covered by a thin coat of dustless screenings, or gravel, spread by hand.

The labor costs include pumping oil from the car tank, hauling same to road, applying same, sweeping road and spreading screenings; also, demurrage on cars and moving tools and repairs, but not cost of the plant.

TABLE 51

			Average cost of materials		Average Quantities of Materials Used		Average Cost	
County	No. Jobs Average	Average Haul, Miles	Oil per Gal. on siding	Cover per Cu. Yd Along Road	Gallons per Sq. Yd.	C. Y. Cover per Sq. Yd	Labor per Sq. Yd.	Total Labor and Material per Sq. Yd
leans	7	2.48	$0.0435	$1.82	0.42	0.016	$0.013	$0.057
agara	4	2.24	0.0425	1.57	0.43	0.016	0.014	0.057
ie	12	2.00	0.0437	1.88	0.34	0.012	0.007	0.045
ie	3	4.41	0.0455	1.83	0.42	0.015	0.019	0.066

Other information would show that cost per mile to sweep erage road is $8.33, cost per gallon applying oil $0.0075; st all labor sweeping, hauling, applying oil and cover about .025 per gal. used

Hot Tar Flush Coats. The cost of applying hot tar flush coats hand is practically the same as given for applying Bituminous nder penetration method.

The writer has no reliable data on the cost of machine appli- .ion.

Calcium Chloride. The cost of applying calcium chloride as emporary dust layer on ten miles of road in Monroe County, Y., as given by Mr. Frank Bristow, First Assistant Engineer, w York State Department of Highways, is as follows:

The material was applied by an ordinary agricultural drill e force used was, 1 horse and driver, $0.30 per hour; 1 helper, 20 per hour No preliminary work of sweeping was done, material was spread on the middle 12 feet of macadam, using proximately 0.75 lbs. to the sq. yd., the average speed being miles, or 3,500 sq. yds., per day, at a cost of $0.0015 per yd.

Cost of calcium chloride at plant	$13.00	net ton
Freight	1.60	per "
Unloading from cars, approximately	0.15	" "
Hauling three miles, "	0.90	" "
Total, delivered on road	$15.65	" "
Total per sq. yd. delivered on road	0.0059	
Labor of spreading	0.0015	
Total per sq. yd. in place	$ 0.0074	

Total per mile 12′ wide, approximately $52.00

Recapping. The cost of recapping with any style of macadam

is practically the same as original construction for that style of work except the item of scarifying and reshaping the old road.

Scarifying. The cost of scarifying, as given by Mr. E. A. Bonney on the Erie County repair work for the season of 1907, is as follows:

COST DATA ON RESHAPING ROAD

Work was done on Main Street Road, No. 69, Erie County, N.Y., between July 15 and Sept. 13, 1907.

The road had been built as a waterbound macadam. It was worn out, particularly in the center. There were few ruts, but the road was nearly level; in some stretches the center was lower than the sides. It was proposed to reshape the road and to lay a new top course treated with tarvia.

The work of reshaping was done by loosening the old surface with spiked wheels of roller; this separated the crust into chunks of various sizes which were broken up by men with picks. The stone was then raked from the sides to the center, brought to the required crown, and rolled until ready for the new course of stone.

The cost of the complete operation included the number of men picking and the rollerman's salary.

Labor	$0.175 per hour
Rollerman	0.300 " "

The roller was rented at a flat rate of $5.00 per day, and a portion of the time it was used on other parts of the work. This cost plus the coal and oil is not included.

The data was compiled daily, and as the work was performed practically every working day between the dates named an average of the square yard price should be nearly correct. The highest cost on any one day was $0.06 per sq. yd., the lowest cost $0.016, and the general average $0.03 per sq. yd.

[1]Through the courtesy of Mr. Halbert P. Gillette, author of "Handbook of Cost Data," we are able to publish the following:

Cost of Resurfacing old Limestone Macadam. "In Engineering News, June 6, 1901, I gave the following data to show that the intermittent method of repairing macadam is the most economic. The data were taken from my timebooks and can be relied upon as being well within the probable cost of similar work done by contract under a good foreman. It will be noted that the cost of operating the roller is estimated at $10.00 per day. This includes interest and depreciation as well as fuel and engineman's wages.

"The road was worn unevenly, but as it still had sufficient metal left, very little new metal was added.

"The roller used was a 12-ton Buffalo Pitts, provided with *steel picks on the* rear wheels. It required eighty hours of rolling

[1] *Gillette's Handbook of Cost Data.* Myron C. Clark Publishing Company, edition of *1907, page 147.* Pages 288 and 289, edition of 1910, in slightly different form.

with the picks in to break up the crust of a surface 19,400 sq. yds. in area, 240 sq. yds. being loosened per hour. The crust was exceedingly hard, and, at times, the picks rode the surface without sinking in, so that a lighter roller would probably have been far less efficient. In fact, a ten-ton roller had been used a few years previous for the same purpose at more than double the expense per square yard, I am told. The picks simply open up cracks in the crust to a depth of about four inches, and it is necessary to follow the roller with a gang of laborers using hand picks to complete the loosening process. The labor of loosening and spreading anew the metal was 1.880 man-hours, or a trifle more than 10 sq. yds. per man-hour, About 60% of this time was spent in picking and 40% in respreading with shovels and potato hooks.

"After the material had been respread, the short section was drenched with a sprinkling cart, water being put on in such abundance that when the roller came upon the metal the screenings which had settled at the bottom in the spreading process were floated up into the interstices. The roller and sprinkling cart were engaged only 63 hours in this process, 300 sq. yds. being rolled per hour; an exceptionally fast rate. The rapidity of rolling was due to four factors: 1. The great abundance of water used, the water being a very short haul. 2. The unyielding foundation (telford) beneath. 3. The abundance of screenings and fine dust, the road not having been swept for some time. 4. The great weight of the roller, which was run at a high rate of speed. I am not prepared to say that longer rolling would not have secured a harder surface, but I doubt very much whether it would. The metal, I should add, was hard limestone. Summing up, we have the cost of resurfacing the road per square yard to have been as follows:

	Cents per sq. yd.
Picking with roller at $1 per hour	0.40
Picking by hand labor at $0.20 per hour	1.20
Respreading by hand labor at $0.20 per hour	0.80
Rolling with roller at $1 per hour	0.33
Sprinkling with cart at $0.40 per hour	0.13
Foreman, 143 hours at $0.30 for 19,400 sq. yds.	0.44
Total	3.30

"At this rate a macadam road sixteen feet wide can be resurfaced for a little more than $300 per mile. The frequency with which such resurfacing is necessary will, of course, depend upon several factors, chief of which are the amount of traffic and the quality of the road metal. I should say that five years would not be far from the average for a country road built of hard limestone. Unless the road has had an excess of metal used in its construction, new metal should be added at the time of resurfacing to replace that worn out.

"I am unable to see how any system of continuous repair *with its puttering* work here and there can be as economical as

work done in the manner above described. I would not be understood, however, as favoring an entire neglect of the road between repair periods. At times of heavy rains and snows, ditches and culverts need attention and there should be some one whose duty it is to look after such matters. What I do question is the economy of having a man continuously at work putting in patches upon the road."

[1]NEW YORK STATE PATROL MAINTENANCE, 1910

The standard Patrol distance is five miles.

The standard Patrol distance, brick roads, is twelve miles.

Patrolman's wages $78 per month, including horse and cart. Patrol is operated eight and one-half months in a year.

The cost of this system of maintenance per mile for 1910 was, approximately, $250 exclusive of administration charges.

Patrolman's wages	$125.00
Materials	125.00
	$250.00

These costs do not include surface treatments. Such a treatment of a road every two years would amount to about $375 a mile per year on waterbound roads.

Automobile Truck Repair System. The tendency on minor repair maintenance work seems to be towards lengthening the patrol distance; confining the duties of the patrolman to cleaning culverts and ditches, trimming shoulders, and reporting the necessity of minor repairs. It is believed that these repairs can be handled more economically from a central point by the use of an automobile truck specially equipped for such work and which can operate within a radius of 20 to 30 miles. Special trucks have been devised with facilities for heating and applying bituminous materials as well as carrying materials.

Conclusion. In conclusion the author desires to again call the attention of the reader to the fact that while cost data is valuable it must be used with discretion and not figured too closely.

[1] Data obtained from Mr. Frank Bristow, Supt. of Repairs, N.Y.S. Dept. of Highways.

CHAPTER XI

NOTES ON CONSTRUCTION

ıtter how well a road is designed, unless the constructing uses good judgment, and the inspection is conscientious ligent, the results will not be satisfactory. This chapter ›es the importance of the different stages of the work and few suggestions as to the manner of meeting common ›s.

g out for Construction. The construction survey picks enter line shown on the plans and by means of offset ·iven to a certain elevation marks the position and ele- ' the road conveniently for building. Any arrangement ; that shows the position of the proposed center line elevation of the proposed grade is satisfactory. These ay be set on one or both sides of the road at intervals 100 feet. The offsets to the center line may be marked to ›st one-tenth foot, or the stakes may be so set that the an even foot, and they may be driven so that the ele- f the proposed grade is above or below them an even -half foot, or an odd tenth. A satisfactory method in ıse in western New York is to set the construction both sides every 50 feet, with an evèn foot offset and such elevation that they are either an even foot or foot above or below grade.

Staking Out					Notes				
Cut or Fill		Levels				Grade	Grade Rod Reading	Rod Reading on Stakes	
L	R	BS	FS	Elev	H.I.	Elev.		L.	R.
				526.42					
F0.5	F1.0	4.17			530.59	524.2	6.4	6.9	7.4
F0.5	F .5				"	524.6	6.0	6.5	7.5
F0.5	F .5				"	525.0	5.6	6.1	7.1
C0.5	F1.0				"	525.4	5.2	4.7	6.2
C0.5	F1.5				"	525.8	4.8	4.3	6.9
C1.0	F2.0				"	526.2	4.4	3.4	6.4
Gr	Gr				"	526.6	4.0	4.0	4.0
Gr	F0.5				"	527.0	3.6	3.6	4.1
Gr	C0.5		3.20	527.39	"	527.8	2.8	2.8	2.3
Gr	C1.0	7.41			534.80	528.6	6.2	6.2	6.2
C0.5	F1.5				"	529.4	5.4	4.9	6.4
F1.0	F1.0				"	530.2	4.6	5.6	5.6
Gr	C1.0				"	531.0	3.8	3.8	2.8
F1.5	C1.0				"	531.8	3.0	4.5	2.0
F1.5	Gr				"	532.6	2.2	3.7	2.2
F1.0	F5.0				"	533.4	1.4	2.4	6.4
					"				

Fig. 67

Such stakes can be readily explained to the ordinary grading foreman so that he has no difficulty in working from them without the assistance of an inspector. The 50-foot interval is convenient for fine grading, as the lines can be stretched this distance with no apparent sag, while if a 100-foot interval is used the sag is objectionable. With stakes on both sides of the road the elevation of the proposed grade can be readily transferred to the center by stretching a line between them and measuring down or up the required amount. This is a much simpler and more accurate method than transferring by straight-edge where two or three lengths of straight-edge must be used from the stake to the center.

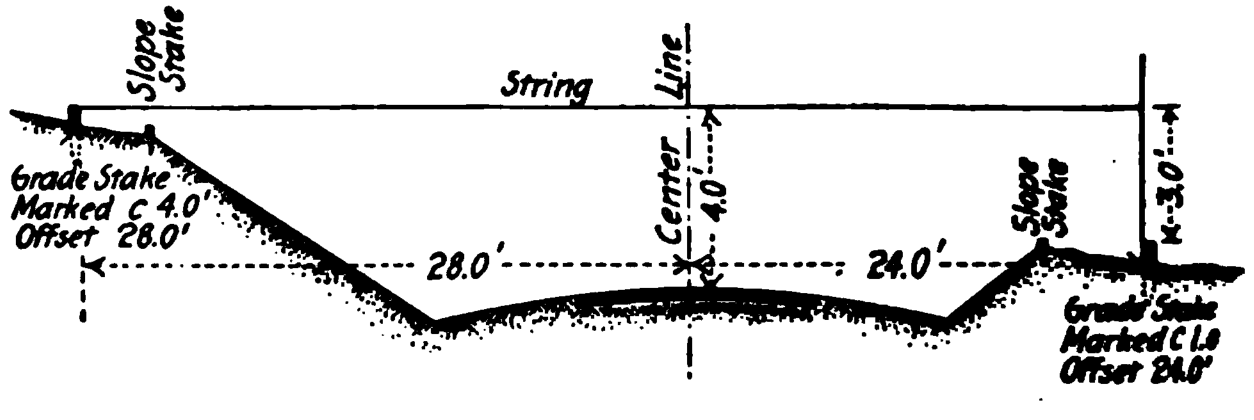


FIG. 68. — Showing Suggested Method of Staking out

The left stake marked C 4.0′ offset 28.0′ means that the crown grade of the finished road is 4.0 feet below the top of this stake and that the proposed center line of macadam is 28.0′ from the face of the stake.

To transfer the proposed grade to the center by the string method. Fasten chalk line to top of left stake; measure up 3.0′ above top of right stake and draw line taut at this elevation. The string is level and 4.0′ above crown grade. Pull as tight as possible, allow about ½″ for sag and measure down 3′ 11½″ for finished grade.

Cost of Staking Out. The speed and cost of staking at 50-foot intervals will, of course, vary with the experience of the men and the character of the road. A party of four men should pick up the proposed center line and set offset stakes on both sides at a speed of 1.5 to 2 miles a day; a party of three men should grade these stakes at a speed of 1.0 to 2.0 miles a day, and the cost of staking out for construction, including livery and board, would be from $20 to $30 per mile.

It is common for new men to spend an unnecessary amount of time in setting the grade stakes. They will often attempt to have the elevation of the grade stakes correct to within 0.01 foot. For all practical purposes, for work of this character, stakes correct to within 0.1 foot in elevation and 0.1 foot in alignment are satisfactory. Curb stakes for village work, however, should be carefully set to within 0.02 foot in elevation and line.

CONSTRUCTION

Rough Grading. By rough grading is meant all of the work preliminary to the finished shaping, and includes moving practically all the dirt that is to be handled. It is particularly important to supervise this stage of construction, as it is here that the constructing engineer regulates the placing of the best material in the center (under the metalling) and the poorer materials on the sides.

In order to grade economically, the contractor and inspector should each be furnished with lists similar to those given below, showing, in a convenient form, the amount of excavation station by station and within what bounds it is to be placed.

Excavation Summary

Sta. to Sta.		Exc.	Emb.	Waste	Borrow
123	134	476	375		
134	140	206	240		
140	157	642	662		165
157	178	766	629		
178	179	231		231	
179	186	298	244		

Detail Quantities

Sta to Sta		Exc	Emb.
123	123+50	575	225
123+50	124	150	900
124	124+50	—	1450
124+50	125	150	900
125	125+50	320	200
125+50	126	170	500
126	126+50	30	825
126+50	127	30	650
127	127+50	260	410
127+50	128	350	250
128	128+50	635	160
128+50	129	635	75

Lists

Remarks

Quantities in cu. yds

Haul from Sta 179 to 150

Quantities in cu. ft

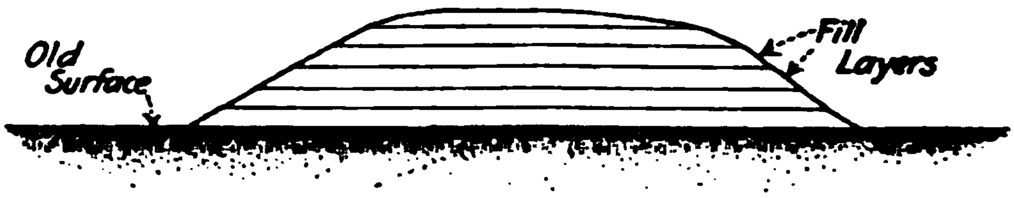
FIG. 69

Cuts. For cuts over 3 feet deep slope stakes are placed and care taken that the slopes are properly carried down. If excavated beyond the finished lines it is practically impossible to make a back-fill that will hold and the resulting irregularities are unsightly.

Fills. For fills slope stakes are set in the same manner as for cuts. The earth should be deposited in thin layers, six to eight inches deep, extending from slope to slope, and each layer well compacted either with a roller or by driving over it with wagons in the process of building. Where the old surface has a steep slope it must be plowed to give a good bond with the new fill and prevent slide.

It is bad practice to build the center of the fill and then shovel

loose material off of the edge to widen the slopes, as this loose side-fill is not compacted and under the action of frost will nearly always slough away from the harder central portion.

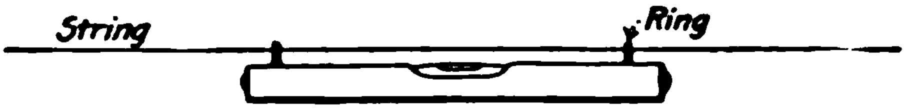


To get the full benefit of the teaming in compacting the dirt, a deep fill should be started at a point nearest the cut from which the material is hauled and each load driven over the loose layer. In this way nearly every fill can be better compacted than by the use of a roller alone. For long fills where there is considerable teaming over each layer a roller is not usually needed.

Wet clay or heavy loam should never be placed in the bottom of a fill, as it dries slowly when not in contact with the air and keeps the fill "spongy." The writer has seen cases where fills not over 3 feet deep have remained soft for two months where wet material had been used and it was finally necessary to remove it.

Transferring Grade from Stakes. A handy level for transferring the grade from stakes to the center of the road is shown below. If well made it will transfer the grade elevation 50 feet with an error of less than 3 inches, which is close enough for this stage of the construction:

Ditches. The ditches *must always* be dug out enough to protect the center grading before the fine grading (stone trench) is completed, and it is usually cheaper for the contractor, as well as better for the road, to dig them out before the fine grading begins.



String Level.

FIG. 70

Regulation of Material in Fills. In fills, particularly shallow ones, the road can be greatly improved by a judicious selection of available materials. Material taken from two nearby cuts, or at different depths in the same cut, will often vary in character and the most experienced man on the job should indicate which materials to use in the center of the fill, under the metalling, and which on the sides. The soils in the order of value for fills are gravel, coarse sand, loam, and clay. For shallow fills on a good foundation clay should not be used under the stone, as mentioned on page 62, and a good material must be overhauled or borrowed. It is better to avoid overhaul if possible, as it is an item liable to be disputed as to the amount. Where it is neces-

sary, a good practical method of determining the amount of the small quantities of earth usually needed is to keep track of the number of wagon loads overhauled from station to station.

Sod may be used in the sides of the fill, but should be kept at least eleven feet off center. It should NEVER be used as a shoulder close to the stone or in the center of the fill under the metalling.

The author wishes to emphasize the importance of this regulation of material. At present the inspection of rough grading is often confined to keeping the sod from the center fill, and the center fill is made of the dirt just as it happens along. As a result, the subgrade will vary greatly in character and if a uniform depth of stone is used over this "spotty" fill the results are often not satisfactory, while if the depth of stone is varied to meet the subgrade conditions an unnecessary amount of stone is used. In cases where there is no choice of earth materials the stone depth must be made thick enough to meet the requirements of the grade.

FINE GRADING FOR STONE TRENCH

The fine grading includes the shaping and consolidation of the stone trench.

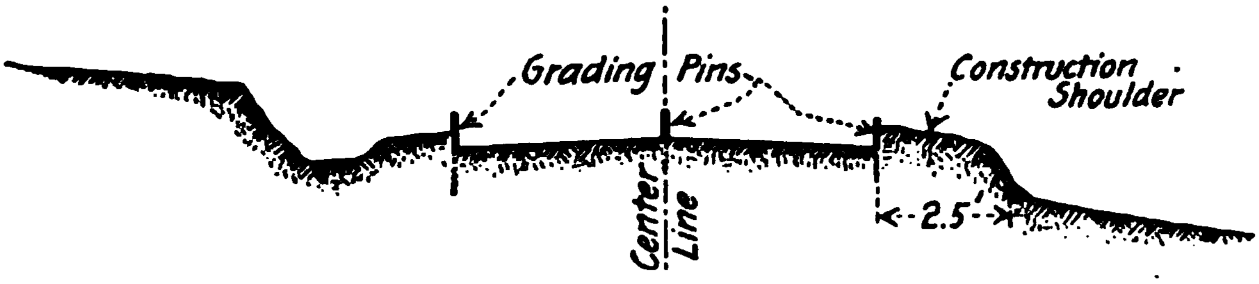


FIG. 71.—Showing 3 Lines of Grading Pins

The construction shoulder must be at least 2.5′ and well consolidated in order to hold the stone solidly during rolling. This must be watched continually by the inspector as it is a point often slighted.

Shaping the Grade. A simple guide for shaping the grade is shown in the accompanying sketch and consists of three strings (center and sides) stretched between pins driven at least every 50 feet and preferably every 25 feet. The pins should not be placed at intervals of more than 50 feet as this will cause objectionable sag in the lines and the grade will be undulating. The grade elevation is transferred and the lines carefully set at their proper elevation by means of a straight-edge, level and rod, or by stretching a line between grade stakes on opposite sides of the road as previously described. The string level recommended for rough grading cannot be used, as it is not sufficiently accurate.

The general level of the finished consolidated grade should be correct to within 1 inch. This leeway of 1 inch from the figured grade *makes it possible* to get satisfactory results without wast-

ing time on finical work and does not appreciably affect the total amount of excavation, as the errors tend to balance. There should, however, be no short, small irregularities of grade noticeable to the eye. Continuous inspection on shaping the grade is not necessary.

Consolidating the Grade. Most soils when slightly moist will consolidate readily if thoroughly rolled. Clay, heavy loams, or excessively fine sandy loams (quicksand) will not pack when wet. Continued rolling is injurious for these soils in this condition, as they will "work" under the roller. If they occur only in small pockets they can be removed and replaced with good material; if in stretches of any length the grade must dry out before placing the stone. Under drains are constructed at this time, where necessary, and the surface ditches are cleaned out and made effective. Where a hard shower has softened the surface only of a previously consolidated grade of this kind and the contractor wishes to lay stone, the surface can be hardened by spreading a thin layer of gravel or waste No. 2 stone and rolling it into the earth. This will help in preventing the stone teams from cutting up the grade.

Gravels and finely pulverized clay, or clay loams (deep dust), will not consolidate when dry; such material must be thoroughly sprinkled to get a compact grade. It is not, however, customary to sprinkle coarse gravels, even if slightly loose, as no objectionable results follows from placing stone on such a grade; deep clay or loam dust is objectionable and must be sprinkled.

Coarse sand makes an ideal foundation but is hard to keep in shape while placing the first layer of stone. In some cases sprinkling will harden it sufficiently; in others a layer of fine loam has been spread over the sand and flushed in with satisfactory results. Sometimes where loam is not available a cheap cheese-cloth has been spread over the top of shifting sand to prevent the stone from punching in too much under the roller. The author has never encountered any coarse sand that could not be successfully treated by sprinkling and covering with 1 inch or 2 inches of No. 2 stone; the blanket of No. 2 stone prevents the sand from squeezing up into the loose bottom stone and spreading the fragments.

While coarse sand makes a good foundation, a fine sand or sandy loam approaching quicksand is very treacherous; it is difficult to judge the degree of fineness at which a sand becomes treacherous, particularly when it is dry. A laboratory method is given on page 62, but a good practical method in the field is to saturate the material thoroughly with water; a satisfactory sand becomes more compact while an exceedingly fine sand gets "quaky."

DETERMINATION OF STONE DEPTHS AND CONSTRUCTION OF SUB-BASE

Practically the only engineering problem that the constructing engineer has to solve is that of foundations. It is recognized by most designers and estimators that it is impossible from even a careful preliminary examination of the soil to specify exactly the amounts and depths of foundation stone. To meet this an extra quantity of sub-base or bottom stone is allowed the constructor, to be used as he sees fit. During the progress of the rough and fine grading the exact limits of the different kinds of subgrade soil are determined and the stone depths varied according to his judgment. (See page 61.) Men that really understand this part of the work are hard to get, as it is only from extended experience and intelligent study of their own failures and successes that a sound judgment is developed. A good constructing engineer is much more difficult to find at present than a good technical designer.

Where sub-base is used the subgrade is dug out to the required extra depth and rolled if it is in such shape that it will not "work." Peat, muck, wet fine sand, or wet clay cannot be rolled until the sub-base is placed and filled. Where it is possible, such soils should be drained and allowed to dry before placing the base, but is often not feasible to dry them enough to allow rolling, even though underdrainage is put in, which partially hardens them and successfully protects the road after the stone has been placed. This is particularly true on flats where it is hard to get an outlet for a drain or in the fine sands on which an under drain has little effect on account of the capillary action of the material. Where a soft subgrade of this kind is encountered, a stony gravel makes the best sub-base, as it contains no voids between the larger fragments and when rolled the soft underlying material cannot squeeze up through the course. In case boulder or quarry stone base is used on a soft grade, it is necessary to lay them in close contact by hand and then fill the voids completely with gravel or No. 2 stone *before* rolling; otherwise the subgrade material would squeeze up between the stones, separating them and partially destroying the efficiency of the base.

In the Spring and Fall of the year it is common to find good material so saturated from long-continued rains that it acts badly under the roller and instead of waiting for the grade to dry out, when the normal thickness of stone would be sufficient, sub-base is often put in either to help the contractor so that he will not be delayed or because the engineer is misled as to the character of the material. This results in a waste of money. On the other hand, clay, when thoroughly dry, is hard and firm, which often influences a new man to omit sub-base where it will surely be needed.

The use of sub-base should not depend too much on the action of the grade under the roller unless the degree of saturation o

the material is considered, although it serves as a guide in locating doubtful spots. The final determination should depend on test pits, which develop the character of the underlying material.

The sub-base is constructed, as explained, in the chapter on Foundations, either of gravel, boulder or quarry stone. The depth is gauged by lines. The ratio of loose to rolled depth is given on page 234.

Continuous imspection is not needed on sub-base; the depth of grading is checked before the stone is placed and the width, depth, and workmanship can be readily determined after the base is completed, and by an occasional inspection during the progress of the work.

Bottom Stone. The earth subgrade must be firm and compact before the stone is spread. Bottom stone must NEVER be laid on a soft grade. One of the most common slips of inspection is to allow this to be done and the result is a "punky" bottom course that is never up to standard. The distributing power of this course depends largely on the stone fragments being firmly interlocked; if the stone is placed on a soft grade and rolled, the earth will squeeze up between the fragments and separate them.

The depth of the loose stone is gauged by the lines or cubical wooden blocks placed on the subgrade. Blocks are more convenient than lines except over sub-base of stone fills, where lines must be used to get a spread true to shape and grade. The ratio of loose to rolled depths is given on page 234.

The loose stone is rolled until the stones are solidly interlocked and there is no movement under the roller. A thin layer of satisfactory filler (see materials page 104) is spread over the top, rolled and broomed in; the process is repeated until the stone is thoroughly filled. Continuous inspection on bottom course is not necessary. The widths and depths can be readily checked by occasional inspection. The two points to be carefully watched during construction are: 1. That the grade is firm; 2. that the loose fragments are thoroughly rolled *before* the filler is applied.

It is desirable to complete the bottom course well in advance of the top, in which case the contractor can work to advantage after rains, and the course will be better compacted by subjecting it to some traffic action.

Where local stone is crushed on the job and the stone used ranges in size from 1 in. to tailings, care must be used in spreading that the sizes are well mixed, as pockets of fine or coarse stone are objectionable. The simplest method of mixing is to run the No. 3 and No. 4 and tailings into one bin at the crusher; if they are separated they can be well mixed by loading one end of the wagons with the No. 3 and the other end with No. 4 and when dumped on the grade they will run together. When difficulty is experienced with these methods in obtaining a well-mixed stone spread the loose stone can be harrowed. Many specifications call for harrowing thoroughly where a large range

: crushed stone size are allowed in one course. If possible, ıilings should be used as sub-base. When used in the bottom ›urse having a rolled depth of 4 or 5 inches they should be placed ı the lower part of the course, but for a 3-inch depth they should e placed on top and broken with a knapping hammer into fragıents of less than 3½ inches.

The filler should not be dumped directly on the stone unless bsolutely necessary. Drawing the loads onto the unfilled :one loosens the course, and, also, at each pile of filler there is pt to be left an excess which is hard to clean off.

Table 52 gives the approximate amount of filler required per ɔo feet, and the spacing of 1½-yard loads. The amount varies ›r the different materials used.

Grading and foundations have been treated at some length, as ıey are the most difficult parts of the construction.

'ABLE 52. GIVING THE APPROXIMATE AMOUNT OF FILLER REQUIRED PER 100 FEET OF ROAD FOR CRUSHED STONE MACADAM BOTTOM COURSES OF DIFFERENT WIDTHS AND DEPTHS, USING 0.35 CUBIC YARDS OF FILLER PER CUBIC YARD OF ROLLED BOTTOM

Width of M'cadam	Rolled Depth of Bottom Course			
	3"	4"	5"	6"
10'	3.2 cu. yds.	4.3 cu. yds.	5.4 cu. yds.	6.6 cu. yds.
12'	3.8 " "	5.1 " "	6.5 " "	7.6 " "
14'	4.5 " "	6.0 " "	7.5 " "	9.0 " "
15'	4.9 " "	6.4 " "	8.0 " "	9.9 " "
16'	5.2 " "	6.9 " "	8.6 " "	10.4 " "
18'	5.9 " "	7.9 " "	9.7 " "	11.8 " "
20'	6.4 " "	8.6 " "	10.8 " "	12.8 " "
22'	7.0 " "	9.4 " "	11.8 " "	14.2 " "

:ABLE 52A. GIVING THE APPROXIMATE SPACING OF 1.5 CUBIC YARD LOADS OF FILLER FOR THE WIDTHS AND DEPTHS SHOWN IN TABLE 52

Width of Macadam	Rolled Depth of Bottom Course			
	3"	4"	5"	6"
10'	46 feet	34 feet	27 feet	23 feet
12'	40 "	30 "	23 "	20 "
14'	33 "	25 "	20 "	17 "
15'	31 "	23 "	19 "	15 "
16'	29 "	22 "	17 "	13 "
18'	25 "	19 "	16 "	12 "
20'	23 "	18 "	13 "	11 "
22'	21 "	16 "	12 "	10 "

TOP COURSES

Waterbound Top. Waterbound top is constructed in the same way as the bottom course except that stone dust is used for a filler and the course is puddled as has been described.

If the stone used is a local stone crushed on the job the output of the crusher must be carefully controlled, especially where selected boulders are used, as it is very important that the size and quality of such stone shall be uniform. (See page 103.) Imported stone can be inspected on the cars. Aside from this, comparatively little inspection is required except at the stage when the loose stone has been rolled and before the binder is spread. At this time the inspector should examine the rolled course very carefully to see that it is true to shape and has no short depressions or humps. The smooth riding quality of the road depends on this inspection and too much care cannot be taken. This point is particularly emphasized, as many of the stone roads in New York State have been criticized as rough for automobile traffic. Any depressions are filled with stone of the same size as the body of the course and rolled, after which the course is again inspected and corrected until it is made true. The binder is then spread, broomed in dry, and puddled. In puddling use plenty of water and roll rapidly. If a pipe line and hose are used a pressure of 100 to 125 pounds at the pump should be maintained. The road can be conveniently puddled in stretches of 100 to 200 feet.

After the road has dried out and been opened to traffic, if raveling occurs it can usually be remedied by light sprinkling and rolling.

Where the top course is granite, gneiss, or trap, it is often necessary to use a certain percentage of limestone dust with the normal screenings. The limestone is more effective when spread last, filling the top voids of the course.

Bituminous Top. Penetration Method. The same procedure applies to the quality, size, and laying of the stone for a bituminous as for waterbound top, and does not require continuous inspection.

Just before pouring the bitumen the course should be carefully examined and any pockets of fine stone, dirt, dirty or dusty stone removed, as fine stone or dirt prevents the penetration of the binder and the bitumen will not adhere properly to the stone unless it is clean and dry. The course is not rolled as firmly at this stage as for waterbound tops because excessive rolling tightens the stone too much and prevents the penetration of the bitumen. There should, however, be no creep in front of the roller. The bitumen is poured into the voids of this *clean, dry, partially* compacted course, usually by means of hand-sprinkling pots or hods. Pots having vertical slots are preferable to the fan-spout pots, as they give better penetration.

Hods are to be preferred to pots. When hods are used, however, the bitumen should be poured across the road instead of in a

inal direction as this prevents overlap and minimizes the
' of preventing humps or waves.
acing the bitumen the following precautions must be
l: It must be hot enough to run freely; for each grade
perature of applications is usually specified and it must
overheated, for if charred it is useless. In applying, by
r method, care must be taken not to overlap, as waves
ps will develop at these points. These defects do not
for some time after the road is opened to travel, and an
enced inspector fails to realize the necessity of care in
ticular. The stone must be clean and dry, and, in the
opinion, the air temperature should not be less than 50° F.,
ien applied in cold weather is so chilled when it strikes the
ne that an excessive amount is retained on the surface.
as the bitumen is applied a thin layer of No. 2 stone is
over the surface and rolled lightly; continued rolling at
nt is injurious, as freshly laid bituminous tops tend to
nder the roller and form waves. The road can be thor-
rolled and shaped to advantage only after the bitumen
some time to harden. Good results have been obtained
ng thoroughly the succeeding day after the binder is
unless in the meantime rain has saturated the course,
ı case it must be allowed to dry before rolling.
mount of bitumen spread per square yard is usually con-
by spreading a given number of pots or hods in a given
f the road. These units of length can readily be marked
he inspector with a stick or tape. This method will be
ory if checked up twice a day by the number of barrels
When the binder is heated in small kettles it will some-
tch fire, but this is usually due to scale which has col-
ı the tank and if cleaned out it generally remedies the

bituminous materials are heated by steam it is often con-
to know the temperature of steam at different pressures;
wing table is inserted for this purpose:

TABLE 53

re bs. In.	Temperature of Steam °F	Pressure Lbs. per Sq. In.	Temperature °F of steam	Pressure Lbs. per Sq. In.	Temperature °F of steam
	213	100	328	200	382
	228	120	341	220	390
	267	140	353	240	397
	293	160	363	260	404
	312	180	373	280	411
	328	200	382	300	417

pounds normal air pressure; to get ordinary steam gauge reading sub-
s. *from the values given in this table.*

BRICK ROADS

To cover the points of construction of brick roads we cannot do better than to give "Instructions for Inspectors," by William C. Perkins, Resident Engineer, New York State Department of Highways. Mr. Perkins is well qualified to judge of this class of work.

Grading. "Read your specifications carefully and follow them in every particular.

"Do not let the contractor dig beyond the back slopes of your ditches. Your ditches should be straight, no sudden jogs; back slopes all true; no rubbish deposited back of the ditches, and be sure that your ditches drain.

"Follow your cross-sections as closely as possible. Try to aid the contractor to take care of his dirt so that when the road is cleaned up there will not be a great amount of material to be moved.

"Never make a shovel fill over 6 inches without rolling it.

"In making a heavy fill with dump wagons begin to dump at the end toward your dirt supply. Have each pile of dump dirt spread thin and draw the next load over this, which will help to pack it. All should then be thoroughly rolled.

"Examine your subgrade carefully, particularly when the roller is going over same, and if it waves or shakes under the roller, sub-base or drain should be put in, or the material dug out and the proper material put in. Do not make a fill with any old material found along the road. Use judgment in this particular.

"Clearing and grubbing does not mean the grubbing of sod. It means the cutting down of bushes, trees, etc. Remember that the life of your pavement is the condition of your subgrade. The same should be inspected by the engineer in charge before any stone or concrete is placed.

"Grade the full width of your macadam or concrete. Never deposit stone in the rut. Keep your sub-base free of ruts.

"If your roller is not working on other work roll your subgrade. You cannot roll it too much.

"Do not shift center line or grades until you have reported the necessity for it to headquarters, and if absolutely necessary give an estimate of the increase or decrease in quantities that such change would make.

"Shoulders should not contain sod within 18 inches of the macadam.

"Back slope all ditches 1 on 1½. Be careful that your gutters are not too deep. Deep gutters where not necessary for drainage purposes make a road dangerous and must be avoided.

"In trimming shoulders and ditches a good inspector should be put on the work, and instructed to see that the contractor sets proper stakes. A stake should be set out from the edge of the macadam, and also one in the ditch, and should be set at least every 100 feet. The bottom of the ditch must be a true

grade, no depression, and the ditch alignment must be good. These stakes can be easily set with a 16-foot level board. When approaching a culvert it is not necessary to deepen the gutters until you reach within 50 feet of same, when a straight grade can then be run to the invert.

"In all cases be sure your ditches will carry water, and, I repeat, be sure they are not ragged and the back slopes are well graded. In trimming shoulders be sure there is no ridge next to the macadam.

"In setting your stakes for the shoulder work use the ordinates and distances shown on the standard section.

"**Subgrade.** Be sure that your subgrade has been properly graded so as to obtain 5 inches of concrete. If the contractor builds the curb first, a templet should be run over the curbing and test made to be sure that you have the correct depth.

"**Concrete Edging.** Stakes for concrete edging can be placed every 50 feet for line and grading, with the exception at change of grades and curves, where they should be placed every 25 feet.

"Be sure that your forms are properly set as to line and grade.

"With stakes 50 feet apart be careful that there is no sag in the line when the forms are set.

"If edging is set first it is better that the concrete be hand-mixed, as a machine turns out too large a quantity and cannot be placed in the proper time.

"See that your forms are wet before the concrete is placed, and if steel forms are used they should be oiled.

"Have a careful inspector on the mixing of the concrete for the edging and watch the mix.

"Keep track of the number of bags of cement used and see that the proper proportion of cement to the lineal foot of edging is obtained.

"Edging 6″ × 10½″ will use 1 bag in 12.95 feet
"Edging 8″ × 10½″ will use 1 bag in 9.73 feet
"Mixture, 1 – 2½ – 5.

"Make the mixture rather wet and spade the same thoroughly, using a hoe straightened and punched full of holes, or some similar instrument, so as to get a good face next to the forms.

"If you find you cannot get a good top surface keep the edging a couple of inches low, and about every third batch mix a batch of fine material and bring the edging up to the proper height, throughly working the same in.

"Do not get a plaster effect, but get a good top surface.

"Round both edges with a rounding tool, making the inner edge of a smaller radius than the outer edge.

"When the forms are taken down all spots which are honeycombed, or rough, should be floated at once with cement. A rough edging should not be left on any road.

"Have the contractor back up the edging as soon as possible.

"*In warm weather* the edging should be kept wet for, at least,

twenty-four hours. Have the contractor use care in delivering materials after the edging is built so that the edges of same are not broken by wagons, etc.

" A good edging is often ruined by carelessness on the part of the contractor.

" **Concrete Base.** Before laying base be sure that the foundation is in proper shape and of a proper depth.

" Lay the concrete rather wet and drag same with a heavy templet. Have men back of the templet with tamping irons or blocks, tamping the concrete. This is important if you wish to get a smooth surface, and you must insist that the concrete be well tamped.

" Be sure that you keep track of your bags, and, also, that the machine is working properly.

" For a 16-ft. road $11\frac{3}{4}$ bags will lay 10 ft. concrete base, mixture $1-2\frac{1}{2}-5$.

" After the day's run examine your base, and if there are any spots which are porous, grout same and check up your bags at the end of each day.

" If the weather is very hot the base should be kept wet for twenty-four hours.

" **Sand Cushion.** Sand for this cushion should be absolutely free of stones, and you must insist that the contractor screen same, if stones are in the sand delivered. No excuses will be taken for stones or pebbles in the cushion. Spread sand for a sufficient depth, then roll same with a small roller; then drag, roll again, and then drag with templet.

" This should be sufficient to give a firm cushion.

" The smoothness of the pavement depends on the proper form of the cushion.

" **Brick.** Great care must be used in obtaining proper brick surface.

" Be sure that your strips on the side expansion joints are in when the contractor starts to lay brick.

" Allow no pinning in at the ends under $2\frac{1}{2}$ inches.

" Be sure that the expansion joint is not ragged. It must be uniform in width, otherwise you will have transverse cracks.

" All bricks should be laid with lugs in the same direction. This is a point that the bricklayers very often do not do. The bricks should be laid by experienced bricklayers, not by amateurs.

" After the brick are laid the contractor will start culling. Then you and your inspectors should carefully go over them, marking all soft[1] bricks to be taken out and rejected; all kiln-marked bricks to be turned over, and if not satisfactory to be taken out and used for pinning in; all overburned bricks.[2]

[1] *Soft brick* are found by sprinkling the pavement lightly; the soft or under-burned *brick will absorb the* moisture, rapidly becoming dull, while the good brick still glisten *with the water.*

[2] *Over-burned brick* are known by their color, which is much darker than the *average.*

which are burned to a cinder to be rejected. All underburned bricks, which, in your opinion, will not make a satisfactory pavement, to be rejected. All bronzed bricks (which have the appearance of overburned brick but this on one side only) to be turned over, and if satisfactory allowed to remain in the pavement.

"Be sure that you have culled all of the bricks before the pavement is rolled, for after the pavement is rolled if much culling is done you are liable to have a rough pavement. After the pavement is rolled go over same and mark all broken and spalled bricks, to be taken out or turned over.

"Be careful of all high and low bricks in the pavement, for same will wear badly when the road is finished.

"Be sure that your bricks are laid at right angles to the curb and are not wavy as to line.

"In no case allow any 'Dutchman'[1] in your pavement except on curves where absolutely necessary.

"**Grouting.** The grouting of the pavement is its life, and the greatest care must be used. Insist that all grout be placed on the pavement by the use of scoops from a box with unequal legs.

"The grout should be mixed in small quantities and of the exact proportions. The sand should be sharp, not too coarse nor too fine. Care should be taken in using lake sand, as same is probably not sharp and too heavy for the grout. As soon as the grout reaches the pavement it should, at once, be pushed into the joints by means of brooms or squeegees.

"It is best to use brooms on the first grouting and a squeegee on the second and third groutings.

"Be sure that the joints are well filled in the first grouting, and do not let the grout escape over the edging and be lost.

"Follow closely with the second grouting, otherwise the two groutings will not unite.

"Be careful that the second grouting does not overlap the first. After the second grouting examine the pavement carefully and, if necessary, put on a third grout to get flush joints.

"The pavement should be completely covered with grout and all joints should be well filled before you pass on same.

"Allow enough time for the grout to obtain initial set, and cover pavement with a layer of sand to protect same from the weather; and pavement should be kept wet for, at least, twenty-four hours.

"In no case permit traffic on the pavement under ten days; longer, if possible.

"**Expansion Joints.** Be careful in removing the expansion joint boards that you do not disturb the pinning-in bricks and break the bond. We found it advisable to use two wedge-shaped boards to make the expansion joints and loosen up the back one as soon as grouting was started.

1 "Dutchman." Brick chipped to wedge shape to fill in between radial courses on curves.

" In pouring the asphalt filler be sure that the joints are absolutely clean the full depth. This is very important, or, otherwise, you will have cracks in the pavement. The joints are to be flushed with asphalt."

CULVERTS

Culverts are usually constructed before the road is graded. They should be completed well in advance of the macadam, because even though the back-fill is carefully tamped there is bound to be some additional settlement under traffic action, and if the macadam is laid over a fresh back-fill depressions are sure to develop which, if not repaired, make "thank-you-marms" in the road.

Cast-Iron Pipe. Trenches for pipe are dug the required depth, making the bottom wide enough to allow the joints to be properly calked. This requires a trench 18″ to 24″ wider than the pipe diameter, i.e., for a 12″ pipe the trench is 30″ to 36″. Bell holes are dug as shown in Fig. 72, so that the pipe will have a uniform bearing its entire length. At no point should it rest directly on boulders or ledge rocks. If the foundation is soft the pipe should be laid on a concrete base. For ordinary soils the only precaution the inspector need take is to prevent back-fill under the pipe.

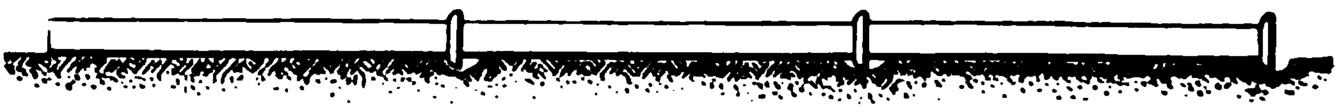


FIG. 72

Unless the foreman is alert the trench is often excavated too much in some places, which are then back-filled. This is bad practice except where boulders are encountered which must be removed and the cavities back-filled with good material.

Pipe. The pipe is inspected for flaws; it is then placed in the trench with the bell end upstream. At each joint the spigot end is placed in the bell and forced against the shoulder, making a tight joint. The pipe is then lined correctly and a gasket of jute or oakum driven into the joint with an iron calking tool having a 2″ to 3″ offset, as shown in Fig. 73. The balance of the joint is then filled with a 1 to 1 cement mortar.

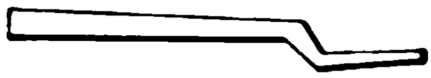


FIG. 73. — Steel Caulking Tool

The trench is then back-filled, care being taken not to throw the pipe out of line; the back-fill must be well tamped in layers *not exceeding 6″*, using heavy paver's rammers. A good working rule is to use two of the best men on the job tamping and the laziest man on the force throwing dirt to them.

Head-walls for Culverts. The face of the head-wall should extend beyond the end of the pipe, as it is difficult to get a good-looking connection if it is flush with the end.

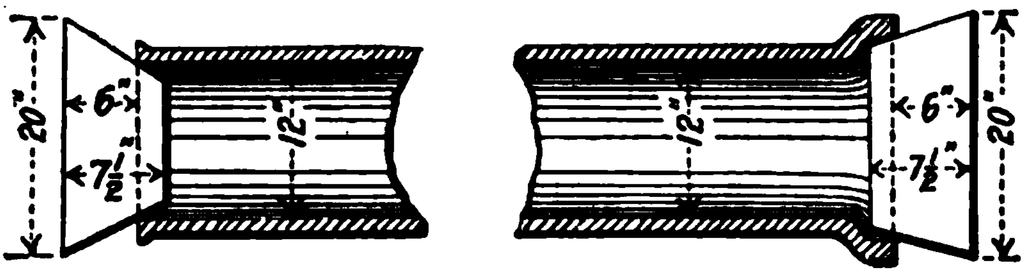


FIG. 74

Figure 74 shows a convenient plug form for this extension. This plug is set into the end of the pipe and can be readily removed; the resulting head-wall being pleasing in appearance. The head-wall form can, also, be readily skewed (set at an angle with the pipe) if required.

CONCRETE CULVERTS

Excavation. The trench is dug to the required depth; if the material will stand vertically no back forms are necessary, and the width of the trench is made the width of the out to out dimensions of the culverts. If back forms are needed the trench is usually made 2 feet wider. If running water is encountered which cannot be temporarily dammed, or diverted, the trench is made wide enough to flume the stream through on one side of the back forms for small culverts, or between the abutments for larger span structures.

Back-fill. The back-fill is made as for cast-iron pipe except that it should not be deposited on the fresh top of a culvert within twenty-four hours of laying the concrete.

Forms. Forms should be true to shape and constructed of planed tongue and groove lumber, for the exposed surfaces. They should be water-tight, as otherwise the fine material will run out of the face of the concrete and leave a rough " pop-corn " surface. They must be well braced to prevent bulging. Triangular or feather-edged grooved moldings are placed in the angles of the forms to shape them satisfactorily.

Removal of Forms. The length of time that the forms should remain in place is a matter of judgment; it depends upon the cement and weather conditions.

The author's practice is as follows:

Head-walls or parapet forms are removed within thirty-six hours in dry weather or within forty-eight hours in damp, cold weather, in order to rub down the surfaces.

Low side-wall forms for spans of 2′ to 3′, where the deck is constructed later, may be removed in 36 to 48 hours.

Trunk forms for small culverts 2′ to 3′ span may be removed in *from 3 to 7 days.*

Trunk forms for medium culverts up to 10′ span 7 to 14 days.

Deck forms for spans above 10′ may be removed in from 14 to 28 days.

Any unusual load, such as a roller, should not be allowed over a new culvert of even a small span in less than seven days, unless precautions are taken to distribute the pressure by planking the back-fill, or otherwise, and on the larger structures a time limit of three to four weeks is advisable.

Amount of Cement, Sand, and Stone required.

Table 49, page 248 gives these amounts for one yard of concrete.

The following table gives the amount of stone, sand, and cement required for culverts similar to Plate 6, assuming that no embedded boulders are used in the sides and bottom. If boulders are used see footnote, Table 49.

MIXING AND PLACING CONCRETE

The strength of the concrete depends largely upon the thoroughness of the mixing.

The author's practice has been as follows:

Hand-mixing. **Cement and Sand.**

3 turns dry....3d class concrete (foundations and side walls)
4 " " ....2d " " (decks and parapets)

Add water and mix mortar.

Drench stone and turn stone and mortar

3 times for 3d class concrete
4 " " 2d " "

Deposit in forms by dropping. Do not cast, as this separates the coarse and fine material. Use enough water to give a mixture that quakes like liver under the rammer.

Deposit in layers not over 6″ deep and ram each layer thoroughly; spade the concrete thoroughly, and work an excess of the fine stuff to the face of the forms by prying the larger fragments back from the form with a narrow spade or broad-tined fork.

Machine-mixing. Culverts generally contain such a small quantity of concrete that machine-mixing is rarely used. In case a batch-mixer is employed, the inspection is simplified to checking the quantities of cement, sand, and stone in each charge. If a continuous mixer is used it is well to keep watch of the cement hopper, as the cement is liable to run low, feeding only a portion of the worm, or a large lump of cement may ride on top of the worm and hinder the feed; or the worm may become coated with damp cement which reduces the capacity. If the inspector watches the cement hopper the contractor will tend to the sand and stone hoppers.

***Finishing* Concrete.** If a smooth, marble-like surface is desired it can be obtained by rubbing down the surface before it has fully set with a cement sand brick moistened with water. If

Concrete Culverts

1.5′ high × 2.0′ wide						
Concrete Cubic Yards		Paving Square Yards	Ex. Met. Square Feet	Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
Second	Third					
2.2	5.6	6.4	80	8.4	3.6	7.2
2.2	5.8	6.4	84	8.6	3.7	7.4
2.3	6.1	6.4	88	9.0	3.9	7.8
2.4	6.3	6.4	92	9.3	4.1	8.1
2.5	6.5	6.4	96	9.7	4.2	8.3
2.5	6.7	6.4	100	9.9	4.3	8.5
2.6	6.9	6.4	104	10.2	4.4	8.8
2.7	7.2	6.4	108	10.6	4.6	9.2
2.8	7.4	6.4	112	10.9	4.8	9.5
2.8	7.6	6.4	116	11.1	4.9	9.6
2.9	7.8	6.4	120	11.5	5.0	9.9
3.0	8.1	6.4	124	11.9	5.2	10.3
3.1	8.3	6.4	128	12.2	5.3	10.6
3.1	8.5	6.4	132	12.4	5.4	10.8
3.2	8.7	6.4	136	12.7	5.6	11.0
3.3	8.9	6.4	140	13.1	5.7	11.3
3.4	9.2	6.4	144	13.5	5.9	11.7
3.4	9.4	6.4	148	13.7	6.0	11.9
3.5	9.6	6.4	152	14.0	6.1	12.1
3.6	9.8	6.4	156	14.5	6.3	12.4
3.6	10.1	6.4	160	14.8	6.4	12.7
3.7	10.3	6.4	164	15.1	6.5	13.0
3.8	10.5	6.4	168	15.4	6.7	13.3
3.9	10.7	6.4	172	15.7	6.8	13.5
3.9	10.9	6.4	176	15.9	6.9	13.7
4.0	11.2	6.4	180	16.4	7.1	14.1
4.1	11.4	6.4	184	16.7	7.2	14.4
4.2	11.6	6.4	188	17.0	7.4	14.7
4.2	11.8	6.4	192	17.2	7.5	14.8
4.3	12.1	6.4	196	17.6	7.7	15.2
4.4	12.3	6.4	200	18.0	7.8	15.5

CONCRETE CULVERTS. — *Continued*

2′ high × 2′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Paving Square Yards	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.4	7.1	80	9.8	10.1	4.4	8.8
21	2.4	7.3	84	9.8	10.4	4.5	9.0
22	2.5	7.6	88	9.8	10.8	4.7	9.4
23	2.6	7.9	92	9.8	11.2	4.9	9.7
24	2.7	8.1	96	9.8	11.5	5.0	10.0
25	2.7	8.4	100	9.8	11.8	5.2	10.3
26	2.8	8.6	104	9.8	12.2	5.3	10.6
27	2.9	8.9	108	9.8	12.6	5.5	10.9
28	3.0	9.2	112	9.8	13.0	5.7	11.3
29	3.0	9.4	116	9.8	13.2	5.8	11.5
30	3.1	9.7	120	9.8	13.6	6.0	11.9
31	3.2	9.9	124	9.8	14.0	6.1	12.1
32	3.3	10.2	128	9.8	14.4	6.3	12.5
33	3.3	10.5	132	9.8	14.7	6.4	12.8
34	3.4	10.7	136	9.8	15.0	6.6	13.0
35	3.5	11.0	140	9.8	15.4	6.8	13.4
36	3.6	11.2	144	9.8	15.8	6.9	13.7
37	3.6	11.5	148	9.8	16.1	7.1	14.0
38	3.7	11.8	152	9.8	16.5	7.2	14.4
39	3.8	12.0	156	9.8	16.8	7.4	14.7
40	3.9	12.3	160	9.8	17.3	7.6	15.0
41	3.9	12.5	164	9.8	17.5	7.7	15.2
42	4.0	12.8	168	9.8	17.9	7.9	15.6
43	4.1	13.1	172	9.8	18.3	8.0	16.0
44	4.2	13.3	176	9.8	18.6	8.2	16.2
45	4.2	13.6	180	9.8	18.9	8.3	16.5
46	4.3	13.9	184	9.8	19.4	8.5	16.9
47	4.4	14.1	188	9.8	19.7	8.6	17.2
48	4.4	14.4	192	9.8	20.0	8.8	17.4
49	4.5	14.6	196	9.8	20.4	8.9	17.7
50	4.6	14.9	200	9.8	20.8	9.1	18.1

CONCRETE CULVERTS. — *Continued*

2′ high × 3′ wide								
…gth …et	Concrete Cubic Yards		Expended Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
0	2.3	7.6	100	78	10.5	4.6	9.2
1	2.4	7.9	105	81	11.0	4.8	9.6
2	2.5	8.2	110	85	11.4	5.0	9.9
3	2.6	8.5	115	88	11.8	5.2	10.3
4	2.6	8.8	120	91	12.1	5.3	10.6
5	2.7	9.1	125	95	12.5	5.5	10.9
6	2.8	9.4	130	98	13.0	5.7	11.3
7	2.9	9.7	135	101	13.4	5.9	11.7
8	3.0	9.9	140	105	13.7	6.0	12.0
9	3.1	10.2	145	108	14.1	6.2	12.3
0	3.2	10.5	150	112	14.6	6.4	12.7
1	3.3	10.8	155	115	15.0	6.6	13.1
2	3.4	11.1	160	118	15.4	6.8	13.4
3	3.5	11.4	165	122	15.9	7.0	13.8
4	3.6	11.7	170	125	16.3	7.2	14.2
5	3.7	12.0	175	128	16.7	7.3	14.6
6	3.8	12.2	180	132	17.0	7.5	14.8
7	3.9	12.5	185	135	17.5	7.7	15.2
8	3.9	12.8	190	139	17.8	7.8	15.5
9	4.0	13.1	195	142	18.2	8.0	15.9
0	4.1	13.4	200	145	18.6	8.2	16.2
1	4.2	13.7	205	149	19.0	8.4	16.6
2	4.3	14.0	210	152	19.5	8.6	17.0
3	4.4	14.3	215	156	19.9	8.7	17.3
4	4.5	14.5	220	159	20.2	8.9	17.6
5	4.6	14.8	225	162	20.7	9.1	18.0
6	4.7	15.1	230	166	21.1	9.2	18.4
7	4.8	15.4	235	169	21.5	9.4	18.7
8	4.9	15.7	240	172	21.9	9.6	19.1
9	5.0	16.0	245	176	22.4	9.8	19.5
0	5.1	16.3	250	179	22.8	10.0	19.8

CONCRETE CULVERTS. — *Continued*

2′ high × 4′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.7	8.4	120	78	11.8	5.2	10.3
21	2.8	8.7	126	81	12.3	5.3	10.7
22	2.9	9.0	132	85	12.7	5.6	11.0
23	3.1	9.3	138	88	13.2	5.8	11.5
24	3.2	9.7	144	91	13.8	6.0	12.0
25	3.3	10.0	150	95	14.2	6.2	12.3
26	3.4	10.3	156	98	14.6	6.4	12.7
27	3.5	10.6	162	101	15.0	6.6	13.1
28	3.6	10.9	168	105	15.5	6.8	13.4
29	3.7	11.2	174	108	15.9	6.9	13.8
30	3.8	11.5	180	112	16.3	7.1	14.2
31	3.9	11.9	186	115	16.8	7.4	14.6
32	4.0	12.2	192	118	17.3	7.6	15.0
33	4.2	12.5	198	122	17.8	7.8	15.5
34	4.3	12.8	204	125	18.3	8.0	15.9
35	4.4	13.1	210	128	18.7	8.2	16.2
36	4.5	13.4	216	132	19.1	8.4	16.6
37	4.6	13.8	222	135	19.6	8.6	17.1
38	4.7	14.1	228	139	20.1	8.7	17.4
39	4.8	14.4	234	142	20.5	9.0	17.8
40	4.9	14.7	240	145	20.9	9.1	18.2
41	5.0	15.0	246	149	21.4	9.4	18.6
42	5.2	15.3	252	152	21.9	9.6	19.1
43	5.3	15.6	258	156	22.3	9.8	19.4
44	5.4	16.0	264	159	22.9	10.0	19.9
45	5.5	16.3	270	162	23.3	10.2	20.2
46	5.6	16.6	276	166	23.7	10.4	20.6
47	5.7	16.9	282	169	24.1	10.6	21.0
48	5.8	17.2	288	172	24.6	10.8	21.3
49	5.9	17.5	294	176	25.0	10.9	21.7
50	6.0	17.8	300	179	25.4	11.1	22.1

CONCRETE CULVERTS. — *Continued*

3′ high × 3′ wide

Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
Second	Third					
2.3	10.4	100	82	13.4	5.9	11.8
2.4	10.8	105	85	13.9	6.2	12.3
2.5	11.2	110	88	14.4	6.4	12.7
2.6	11.5	115	92	14.9	6.6	13.1
2.6	11.9	120	95	15.3	6.8	13.5
2.7	12.2	125	99	15.7	7.0	13.8
2.8	12.6	130	102	16.2	7.2	14.3
2.9	13.0	135	105	16.8	7.4	14.8
3.0	13.3	140	109	17.2	7.6	15.1
3.1	13.7	145	112	17.7	7.9	15.6
3.2	14.0	150	116	18.2	8.1	16.0
3.3	14.4	155	119	18.7	8.3	16.4
3.4	14.8	160	122	19.2	8.5	16.9
3.5	15.1	165	126	19.6	8.7	17.3
3.6	15.5	170	129	20.2	8.9	17.6
3.7	15.8	175	133	20.6	9.1	18.1
3.8	16.2	180	136	21.1	9.4	18.6
3.9	16.6	185	139	21.6	9.6	19.0
3.9	16.9	190	143	22.0	9.7	19.3
4.0	17.3	195	146	22.5	10.0	19.8
4.1	17.6	200	150	22.9	10.2	20.1
4.2	18.0	205	153	23.4	10.4	20.6
4.3	18.4	210	156	24.0	10.6	21.1
4.4	18.7	215	160	24.4	10.8	21.4
4.5	19.1	220	163	24.9	11.0	21.9
4.6	19.4	225	167	25.4	11.2	22.3
4.7	19.8	230	170	25.9	11.4	22.7
4.8	20.2	235	173	26.4	11.7	23.2
4.9	20.5	240	177	26.8	11.9	23.6
5.0	20.9	245	180	27.4	12.1	24.0
5.1	21.2	250	184	27.8	12.3	24.4

CONCRETE CULVERTS. — *Continued*

3′ high × 4′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	2.7	11.3	120	82	14.8	6.5	13.0
21	2.8	11.7	126	85	15.3	6.8	13.5
22	2.9	12.1	132	88	15.8	7.0	13.9
23	3.1	12.5	138	92	16.5	7.3	14.5
24	3.2	12.9	144	95	17.0	7.5	14.9
25	3.3	13.2	150	99	17.4	7.7	15.3
26	3.4	13.6	156	102	18.0	7.9	15.8
27	3.5	14.0	162	105	18.5	8.2	16.3
28	3.6	14.4	168	109	19.0	8.4	16.7
29	3.7	14.8	174	112	19.6	8.7	17.2
30	3.8	15.2	180	116	20.1	8.9	17.6
31	3.9	15.6	186	119	20.6	9.1	18.1
32	4.0	16.0	192	122	21.1	9.4	18.6
33	4.2	16.4	198	126	21.8	9.6	19.1
34	4.3	16.8	204	129	22.3	9.8	19.6
35	4.4	17.1	210	133	22.8	10.1	20.0
36	4.5	17.5	216	136	23.3	10.3	20.4
37	4.6	17.9	222	139	23.8	10.5	20.9
38	4.7	18.3	228	143	24.3	10.8	21.3
39	4.8	18.7	234	146	24.9	11.0	21.8
40	4.9	19.1	240	150	25.4	11.2	22.3
41	5.0	19.5	246	153	25.9	11.4	22.7
42	5.1	19.9	252	156	26.5	11.7	23.2
43	5.3	20.3	258	160	27.1	12.0	23.7
44	5.4	20.7	264	163	27.7	12.2	24.2
45	5.5	21.0	270	167	28.1	12.4	24.6
46	5.6	21.4	276	170	28.6	12.6	25.0
47	5.7	21.8	282	173	29.1	12.9	25.5
48	5.8	22.2	288	177	29.7	13.1	26.0
49	5.9	22.6	294	180	30.2	13.3	26.4
50	6.0	23.0	300	184	30.7	13.6	26.9

Concrete Culverts. — *Continued*

4′ high × 4′ wide

th t	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushe Stone Cubic Yards
	Second	Third					
	2.7	14.5	120	87	18.1	8.1	15.9
	2.8	15.0	126	90	18.7	8.3	16.5
	2.9	15.4	132	94	19.2	8.6	17.0
	3.1	15.9	138	97	20.0	8.9	17.6
	3.2	16.4	144	100	20.6	9.2	18.2
	3.3	16.8	150	104	21.1	9.4	18.7
	3.4	17.3	156	107	21.8	9.7	19.2
	3.5	17.7	162	111	22.3	9.9	19.7
	3.6	18.2	168	114	22.9	10.2	20.2
	3.7	18.7	174	117	23.5	10.5	20.8
	3.8	19.1	180	121	24.1	10.7	21.2
	3.9	19.6	186	124	24.7	11.0	21.8
	4.0	20.1	192	128	25.3	11.3	22.4
	4.2	20.5	198	131	26.0	11.6	22.9
	4.3	21.0	204	134	26.6	11.9	23.5
	4.4	21.4	210	138	27.1	12.1	24.0
	4.5	21.9	216	141	27.8	12.4	24.5
	4.6	22.4	222	145	28.4	12.6	25.1
	4.7	22.8	228	148	28.9	12.9	25.5
	4.8	23.3	234	151	29.6	13.1	26.1
	4.9	23.8	240	155	30.2	13.4	26.6
	5.0	24.2	246	158	30.7	13.7	27.1
	5.1	24.7	252	162	31.4	14.0	27.7
	5.3	25.2	258	165	32.1	14.3	28.3
	5.4	25.6	264	168	32.6	14.5	28.8
	.5	26.1	270	172	33.3	14.8	29.3
	.6	26.5	276	175	33.8	15.0	29.8
	.7	27.0	282	179	34.4	15.3	30.3
	8	27.5	288	182	35.1	15.6	30.9
	9	27.9	294	185	35.6	15.8	31.4
	)	28.4	300	189	36.2	16.1	31.9

CONCRETE CULVERTS. — *Continued*

3′ high × 5′ wide							
Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	4.0	12.4	140	83	17.5	7.7	15.2
21	4.2	12.8	147	86	18.1	7.9	15.7
22	4.4	13.3	154	90	18.9	8.3	16.4
23	4.6	13.7	161	93	19.5	8.6	17.0
24	4.7	14.1	168	96	20.1	8.8	17.4
25	4.9	14.5	175	100	20.7	9.1	18.0
26	5.1	14.9	182	103	21.4	9.3	18.5
27	5.3	15.4	189	106	22.1	9.6	19.2
28	5.4	15.8	196	110	22.6	9.9	19.7
29	5.6	16.2	203	113	23.3	10.2	20.2
30	5.8	16.6	210	117	23.9	10.5	20.8
31	5.9	17.0	217	120	24.5	10.7	21.2
32	6.1	17.4	224	123	25.1	11.0	21.8
33	6.3	17.9	231	127	25.9	11.3	22.4
34	6.5	18.3	238	130	26.5	11.6	23.0
35	6.6	18.7	245	134	27.1	11.8	23.5
36	6.8	19.1	252	137	27.7	12.1	24.0
37	7.0	19.5	259	140	28.4	12.4	24.6
38	7.2	19.9	266	144	29.0	12.7	25.1
39	7.3	20.4	273	147	29.6	12.9	25.7
40	7.5	20.8	280	150	30.3	13.2	26.2
41	7.7	21.2	287	154	30.9	13.5	26.8
42	7.8	21.6	294	157	31.5	13.7	27.3
43	8.0	22.0	301	161	32.1	14.0	27.8
44	8.2	22.4	308	164	32.8	14.3	28.4
45	8.4	22.9	315	167	33.4	14.6	29.0
46	8.5	23.3	322	171	34.1	14.8	29.5
47	8.7	23.7	329	174	34.7	15.1	30.0
48	8.9	24.1	336	177	35.3	15.3	30.6
49	9.1	24.5	343	181	36.0	15.6	31.2
50	9.2	24.9	350	184	36.5	15.9	31.6

CONCRETE CULVERTS. — *Continued*

4′ high × 5′ wide							
Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
Second	Third					
4.0	15.8	140	88	21.0	9.2	18.4
4.2	16.3	147	92	21.7	9.6	19.0
4.4	16.8	154	95	22.5	9.9	19.7
4.6	17.2	161	99	23.1	10.2	20.2
4.7	17.7	168	102	23.7	10.5	20.8
4.9	18.2	175	105	24.5	10.8	21.4
5.1	18.7	182	109	25.2	11.1	22.1
5.3	19.2	189	112	26.0	11.5	22.7
5.4	19.7	196	116	26.6	11.7	23.3
5.6	20.2	203	119	27.4	12.1	23.9
5.8	20.7	210	122	28.1	12.4	24.6
5.9	21.2	217	126	28.8	12.7	25.1
6.1	21.7	224	129	29.5	13.0	25.8
6.3	22.1	231	133	30.2	13.3	26.3
6.5	22.6	238	136	30.9	13.6	27.0
6.6	23.1	245	139	31.5	13.9	27.6
6.8	23.6	252	143	32.3	14.2	28.2
7.0	24.1	259	146	33.0	14.5	28.8
7.2	24.6	266	150	33.8	14.9	29.5
7.3	25.1	273	153	34.4	15.1	30.1
7.5	25.6	280	156	35.2	15.5	30.7
7.7	26.1	287	160	35.9	15.8	31.3
7.8	26.6	294	163	36.6	16.1	31.9
8.0	27.0	301	167	37.2	16.4	32.5
8.2	27.5	308	170	38.0	16.7	33.1
8.4	28.0	315	173	38.7	17.0	33.8
8.5	28.5	322	177	39.3	17.3	34.3
8.7	29.0	329	180	40.1	17.6	35.0
8.9	29.5	336	184	40.9	18.0	35.6
9.1	30.0	343	187	41.6	18.3	36.3
9.2	30.5	350	190	42.2	18.6	36.8

CONCRETE CULVERTS. — *Continued*

5′ high × 5′ wide

Length Feet	Concrete Cubic Yards		Expanded Metal Square Feet	Steel Pounds	Portland Cement Barrels	Sand Cubic Yards	Crushed Stone Cubic Yards
	Second	Third					
20	4.0	19.5	140	93	24.7	11.0	21.8
21	4.2	20.0	147	96	25.5	11.3	22.5
22	4.4	20.6	154	100	26.3	11.7	23.2
23	4.6	21.2	161	103	27.2	12.1	24.2
24	4.7	21.7	168	106	27.8	12.4	24.8
25	4.9	22.3	175	110	28.7	12.7	25.4
26	5.1	22.9	182	113	29.5	13.1	26.2
27	5.3	23.4	189	117	30.3	13.4	26.8
28	5.4	24.0	196	120	31.0	13.8	27.6
29	5.6	24.6	203	123	31.9	14.1	28.2
30	5.8	25.1	210	127	32.6	14.5	29.0
31	5.9	25.7	217	130	33.4	14.8	29.6
32	6.1	26.2	224	134	34.1	15.1	30.2
33	6.3	26.8	231	137	35.0	15.5	31.0
34	6.5	27.4	238	140	35.8	15.9	31.8
35	6.6	27.9	245	144	36.4	16.2	32.4
36	6.8	28.5	252	147	37.3	16.5	33.0
37	7.0	29.1	259	150	38.2	16.9	33.8
38	7.2	29.6	266	154	38.9	17.2	34.4
39	7.3	30.2	273	157	39.6	17.6	35.1
40	7.5	30.8	280	161	40.5	17.9	35.8
41	7.7	31.3	287	164	41.2	18.3	36.5
42	7.8	31.9	294	167	42.0	18.6	37.2
43	8.0	32.5	301	171	42.8	19.0	37.0
44	8.2	33.0	308	174	43.6	19.3	38.6
45	8.4	33.6	315	178	44.4	19.7	30.3
46	8.5	34.2	322	181	45.2	20.0	40.0
47	8.7	34.7	329	184	45.9	20.3	40.6
48	8.9	35.2	336	188	46.7	20.6	41.2
40	9.1	35.9	343	191	47.6	21.0	42.0
50	9.2	36.4	350	195	48.3	21.4	42.8

a rough sandpaper-like finish is wanted it can be secured by rubbing with a wooden float moistened with water. This finish is not as apt to hair-check as the smooth finish.

Freshly laid concrete should be protected from a hot sun by covering it with canvas, or blankets, and wetting it down frequently for four or five days. No plastering of surfaces should be allowed after the cement has set. If, however, it has been badly hair-checked from heat the defect can usually be remedied by rubbing with a carborundum brick. Freshly laid concrete must be protected from frost. A satisfactory method is to cover with canvas and a thick layer of manure or straw. If the concrete has been frost-pitted, on the surface only, bush hammering will give a rough stone finish, pleasing in appearance. No culvert work should be allowed in continued cold weather, as it is difficult to get a good finish and in roadwork there is no necessity of doing this work in the winter. Concrete inspection must be *continuous*.

CONCLUSION

For obvious reasons the inspection of construction is generally the weak point in Municipal and State Engineering undertakings. It is often due to the employment of inferior inspectors, and frequently to the impossibility of even good inspectors controlling certain contractors. The work is rarely bad, but it will not be as strong nor as lasting as a first-class job, and if such conditions are foreseen, and cannot be avoided, it is, perhaps, best to design the work stronger than would otherwise be required, as this seems to be the only practical method of meeting a recognized evil.

CHAPTER XII

SPECIFICATIONS

UNDER this heading are included extracts from the State specifications of New York and Washington covering "Materials" and the more common construction methods. It is difficult to write a specification that is definite and fair, and it is impossible to avoid criticism. The following clauses are examples of current practice. They are not ideal, but show the points to be considered. No attempt is made in this book to discuss methods of bidding or of forms of proposals.

MATERIALS

(NEW YORK STATE SPECIFICATIONS, 1911)

Quality of Broken Stone. Only broken stone and screenings accepted by the Commission will be allowed in the work, and in all cases they must be of a hard and compact texture and of a uniform grain. The fragments shall have rough surfaces such as are obtained by fracture. Water-worn pebbles will not be accepted. Disintegrated and rotten stone from the surface of a quarry or elsewhere will not be accepted. All stone shall be thoroughly clean before crushing and must be well screened, and free from injurious matter of every nature.

Field stone, boulders, or fence stone which are crushed for macadam purposes shall be six or more inches in diameter if consisting of rounded cobbles. If of the flat variety, the minimum thickness allowed is two inches, which latter will also apply to laminated quarry stone.

Selected Gravel. Gravel satisfactory to the Commission shall be placed on the surface of the roadway where called for on the plans; the width and thickness after being rolled shall be as there shown. It shall be composed of hard, durable stone and assorted sizes of finer materials, sufficient but no more than sufficient to fill all the voids. All stones that will not pass through a two and three-quarter inch circular ring shall be removed. It shall be sprinkled until thoroughly wet and rolled with a self-propelled grooved road-roller weighing approximately ten tons until smooth and thoroughly consolidated. Under no circumstances shall shale gravel be used.

Gravel for Bituminous Pavement. Gravel when specified must be tested and approved by the Commission. It shall be separated into four grades by means of screens having circular openings of the following diameters: $\frac{5}{8}$-inch, $1\frac{1}{4}$ inches, $2\frac{1}{4}$ inches, and $3\frac{1}{2}$ inches. These grades will hereinafter be designated as gravel screenings, No. 2 gravel, No. 3 gravel, and No. 4 gravel.

Any material which will pass a screen having openings ¼ of an inch square will be classified as dust.

Filler or Binder. The filler for the bottom course shall be clean, coarse sand or stone screenings supplemented by product of the crusher not otherwise used in top or bottom courses. The filler and wearing surface for the top course shall be of top course stone screenings and when bituminous binder is used screenings must be dry, free from dust, and not larger than will pass a ⅜-inch screen.

BITUMINOUS MATERIALS

Methods of Testing Bituminous Materials in the Laboratory of the Commission

Preparing Laboratory Samples. Each laboratory sample is usually composed of several samples that have been taken to represent one lot of material. The material in the separate samples is examined, and, if uniform in appearance, equal amounts are taken from each and thoroughly blended to form a sample of about one-half pint on which the complete analysis is run.

In case of mineral bitumen, the sample received is thrown on a large piece of paper, pieces which are evidently foreign to the material are rejected, and the whole "quartered down" to a sample of about 300 grams. This is ground in a mortar and the analysis run on this part of the original sample.

Water Present. The presence of water in an oil, asphalt, or tar is determined by putting about 40 grams of the material into a deep, seamless 3-ounce tin box, a thermometer being suspended in the material. This is then heated to about 230° F. without stirring. If water is present, even in very small quantities, the material will froth when heated to about 212° F. The per cent of water present is determined by heating 20 grams of the material in a 2-ounce seamless tin box in an oven maintained at a temperature of 212° F. for an hour. The per cent of water in mineral bitumen is determined in a similar manner. The loss in weight, while not absolutely correct, is considered as moisture.

Homogeneity. The homogeneity of the mixture is shown by its general appearance at a temperature of 77° F. when in a melted condition and when examined under the microscope.

Gravity. The gravity is determined by taking a small test tube about ⅝ of an inch by 3¼ inches, which is accurately weighed (weight A). The tube is then filled with distilled water at 77° F. and weighed (weight B). To get the gravity of the oil, asphalt, or tar the tube is filled with the material, cooled to a temperature of 77° F., cut off level with the top, and weighed (weight C). The gravity is determined as follows: $\frac{C - A}{B - A}$ = gravity.

Penetration. The penetration tests are made by putting the *material to be tested in* a 3-ounce deep, seamless tin box, placing

the box in water maintained at 77° F. for a period of 2 hours before making the penetration tests. The tests are made with a New York Testing Laboratory Penetrometer using a No. 2 needle, 100-gram weight, the load being applied for 5 seconds.

Residue having a Penetration of 10 Millimeters. This test is made as follows: 50 grams of the oil are placed in a 3-ounce deep, seamless tin box, the box placed in a sand bath and heated over a Bunsen Burner. A thermometer is suspended in the oil, the bulb not touching the bottom of the box. The temperature of the oil is kept at from 480° F. to 500° F. and the oil is stirred from time to time with the thermometer to prevent overheating in any part. Depending upon the nature of the oil, as usually indicated by its flash, consistency at 77° F. and gravity, the operator can tell about what per cent it will be necessary to evaporate before cooling and taking a penetration as described under the test for penetration. It is sometimes necessary to make several trials before the desired result is obtained. When the required penetration is reached, the residue left from evaporation is weighed and its per cent of the original sample taken is computed.

Ductility. The ductility of an asphalt cement or bitumen is determined by the distance in centimeters that a briquette of the material will draw out before breaking. The briquette of the asphalt cement is molded in a Dow briquette mold having a central cross-section 1 centimeter square, a 2-square centimeter cross-section at mouth of clips, and a distance of 3 centimeters between clips. The molding of the briquette is done as follows: The mold is placed on a brass plate. To prevent the asphalt cement from adhering to this plate and the inner sides of the two pieces of the mold, they shall be well amalgamated. The asphalt cement to be tested is poured into the mold while in a molten state, a slight excess being added to allow for shrinkage on cooling. After the asphalt cement is nearly cooled, the briquette is smoothed off level by means of a hot spatula. When it is thoroughly cooled to the temperature at which it is desired to make the test, the clamp and the two side-pieces are removed, leaving the briquette of asphalt cement held at each end by the ends of the mold which serve as clips. The test is made by pulling the two clips apart at a uniform rate of 5 centimeters per minute by means of hooks inserted in the eyes, until rupture occurs. The briquette is kept in water at 77° F. for at least 30 minutes before testing, and the test is performed while the briquette is so immersed in the water at the above temperature, and at no time is the temperature of the water allowed to vary more than half a degree from the standard temperature.

Torsion. The torsion test is made by rolling with the hands a roll ½ inch in diameter having a working length or distance between gripping points of 6 inches. The roll is cooled in water to 15° C. for 30 minutes and the torsion made immediately upon taking the roll from water by gripping the roll with the fingers,

the length of the roll being 6 inches between the fingers. Three complete turns of one end of the roll are made and it is then examined for cracks. A similar roll cooled in a similar manner is stretched for a distance of at least 3 feet by pulling slowly with the hands.

Melting Point of Bitumen. The melting or softening point of bitumen is determined by filling a ring ⅝ inch in diameter by ¼ inch in depth, with the bitumen to be tested. After cooling, the bitumen is cut off level with the top of the ring. The ring containing the bitumen is placed in water at 65° F. for 20 minutes before making the test. In performing the test the ring is put in a support so placed that the bottom of the ring is 1 inch above the bottom of an 800 cc. beaker. On the center of the bitumen in the ring, is placed a ⅜-inch steel ball, a thermometer being placed with its bulb on a level with the ring containing the bitumen. The beaker is nearly filled with water at a temperature of 65° F. and the temperature raised at the rate of 8° F. to 10° F. per minute. The temperature recorded by the thermometer at the time the ball touches the bottom of the beaker is taken as the melting point of the bitumen.

Heating Tests. The heating tests at 325° F. and 400° F. are made by weighing 20 grams of the material for each test into 2-ounce seamless tin boxes 2½ inches by ¾ inch. The boxes are then placed in ovens maintained at 325° F. and 400° F. for 5 hours and the loss in weight, or per cent of loss at the end of that period, found.

Flash. About 40 grams of the material to be tested are placed in a 3-ounce deep, seamless tin box. The box containing the material is placed on a sand bath over a Bunsen Burner, the bulb of a thermometer being placed in the material, but so adjusted as not to touch the bottom of the box. The flame of the Bunsen Burner is so adjusted that the temperature of the material being tested is raised at the rate of 10° F. to 15° F. per minute. As soon as vapors are seen coming off, the small flame from a capillary tube is passed over the center of the liquid and about ¼ inch above it, and repeated for about every 5° F. rise in temperature until the slight explosion indicates the flash-point is reached. The temperature at this point is recorded as the open flash-point of the material being tested.

Total Bitumen. The solubility in $C S_2$ is found by weighing approximately 1 gram of the material into an Erlenmeyer flask, adding 50 cc. of $C S_2$ and allowing the solvent to act 12 hours at laboratory temperature, care being taken to break up all lumps before filtering. The filtration is made through a C. S. & S. 9-centimeter filter paper No. 589. The papers are first dried, and weighed immediately before using. The filtration is made in a valve funnel, a watch glass being placed on the funnel to prevent evaporation of the solvent. After washing until washings come clean, the filter and residue are placed in an oven at 212° F. for 30 minutes, cooled in a desiccator and

weighed. The difference in weight gives the amount of material insoluble in $C S_2$ from which the per cent of soluble bitumen is computed.

The total bitumen in mineral bitumen is determined by weighing about 25 grams of the dried material into a dried and weighed C. S. & S. extraction cartridge and extracting in a continuous extraction apparatus, using $C S_2$ for a solvent; drying and weighing after extraction is completed. The loss gives the amount of bitumen soluble in $C S_2$.

Carbon Tetrachloride Solubility. This test is made in the same manner as determining the bitumen soluble $C S_2$, except that $C C l_4$ is used as solvent.

Naphtha Solubility. The amount of material soluble in 76° naphtha (boiling point 140° F. to 190° F.) is found by the same method that is used in getting the amount soluble in $C S_2$, except that naptha is used for a solvent in place of $C S_2$. The character of the filtrate is determined by placing about 10 cc. of the filtrate in the tin covers of the 2-ounce boxes used in making the heating tests and allowing the filtrate to evaporate. The residue is noted to be sticky or oily by rubbing between the fingers.

Water Soluble Materials. Water soluble materials in tar are determined by weighing about 2 grams into a casserole, adding 50 cc. of distilled water, and boiling for 1 hour. The solution is then filtered into a weighed porcelain evaporating dish, using hot distilled water for a wash and evaporated to dryness on a steam bath. The weight of the evaporating dish and contents after drying to a constant weight of 212° F., less the weight of the dish itself, gives the amount of water soluble materials in the tar, from which the per cent may be calculated.

Free Carbon. The free carbon in tar is determined by extraction at room temperature with $C S_2$. In extraction $C S_2$ is used in the same manner as making the determination for the amount of bitumen soluble in $C S_2$ in asphalts. Determination as to whether extraction is complete is made by placing some of the carbon on white porcelain, moistening it with $C S_2$, and if the porcelain is stained the extraction is not complete, and the carbon requires more washing.

Paraffine. Fifty grams of the material are placed in a half-pint retort, E. & A. No. 4521, fitted with a tee condenser. To the 20-inch iron delivery tube of the retort is attached a 10-inch glass tube, and between the cover and the retort is placed a paper gasket cut from heavy wrapping-paper. The material is rapidly distilled to a dry coke from which no further distillate can be obtained, not over 25 minutes being allowed from the time of placing flame under retort until distillation ceases. About 5 grams of the distillate are taken if the materials contain 2 per cent or less of paraffine and about 3 grams if the material contains over 2 per cent of paraffine. This amount of distillate is dissolved in 25 cc. of Squibbs Absolute Ether in a 2-ounce glass flask, after which 25 cc. of Squibbs Absolute Alcohol are

added. A one-to-one wash of 25 cc. each of similar ether and alcohol is made up, and the solution of oil and the wash are then frozen separately for 40 minutes in a salt and ice mixture, giving a temperature of 0° F. The precipitate is filtered quickly by means of a suction pump by using a No. 575 C. S. & S. 9-centimeter hardened filter-paper; the paper being placed in a funnel packed in a freezing mixture of salt and ice. The paraffine caught on the filter-paper is washed with the cool one-to-one wash until the paraffine is white. The paraffine is then scraped into a weighted crystallizing dish and maintained at a temperature of 212° F. until a constant weight is obtained, after which it is weighed and the percentage of paraffine in the original material is computed by dividing the weight of the paraffine obtained by the number of grams of distillate taken for freezing, and multiply this result by the percentage distilled from the original sample (i.e., by 100 per cent less weight of coke expressed in percentage). The paraffine so determined to have a melting point of at least 120° F.

The melting-point of paraffine is determined by covering the bulb of a thermometer with the paraffine; suspending the thermometer in a beaker of water at 65° F., and heating the water at the rate of 8° to 10° F. per minute. The temperature recorded by the thermometer at the time the paraffine melts from the bulb is taken as the melting-point of the paraffine.

Distillation of Tar. The distillation test of tar is made by weighing 100 grams of the tar into a 250 cc. Engler flask with delivery tube at the middle of the neck. The thermometer is so placed that the upper end of the mercury bulb is opposite the outlet of the flask. The thermometer used to have a nitrogen chamber to insure accurate readings at high temperatures. The flame is so regulated that approximately 1 cc. of distillate is caught per minute. At the breaking or fractioning points, the flame is removed and the temperature is allowed to drop about 10°; the flame is then replaced and the temperature brought to the fractioning point. This is repeated until all is over that will come at that temperature. The temperature is then carried to the next fractioning point and the method of fractioning repeated. The distillates for the different fractioning points are caught, weighed, and per cent of distillate of tar taken for analyses, computed for the various temperatures, percentages being given by weight.

Fixed Carbon and Mineral Matter. The fixed carbon is determined by weighing approximately 1 gram of the material into a weighed platinum crucible with a tightly fitting cover. The crucible, with its cover in place, is then placed about 4 inches over a freely burning Bunsen Burner so as to be completely enveloped in the flame and exposed to the full heat of the burner for about 3 minutes or until the top of the crucible cover is burned free from the carbon; the under side of the cover being covered with the carbon. The flame is then withdrawn, the

crucible cooled and weighed. The weight after burning, less the weight of the crucible, gives the amount of fixed carbon plus the mineral matter. The fixed carbon is then burned off in the open crucible until a constant weight is obtained; the crucible cooled and weighed. This weight is the crucible plus the mineral matter. The mineral matter subtracted from the combined weight of fixed carbon and mineral matter gives the fixed carbon.

BITUMINOUS MATERIAL A

Mastic for Bituminous Macadams

Bituminous material A shall have the following characteristics:

(1) It shall be free from water or decomposition products.

(2) The various hydrocarbons composing it shall be present in homogeneous solution, no oily or granular constituents being present. The material shall not be short, and shall show satisfactory ductility and adhesiveness.

(3) The gravity at a temperature of 77° F. shall not be lighter than 13 Beaumé.

(4) The penetration shall be between 12 and 18 millimeters when tested for 5 seconds at 77° F. with a No. 2 needle weighted with 100 grams.

(5) Twenty (20) grams of it upon being maintained at a uniform temperature of 325° F. for five hours in a cylindrical vessel 2½ inches in diameter by ¾ inch high shall not lose more than 4 per cent in weight.

(6) Twenty grams of it upon being maintained at a uniform temperature of 400° F. for five hours as above stated shall not lose more than 8 per cent. The character of the residue at 77° F. shall be smooth and nearly solid, but not so hard that it may not be easily dented with the finger.

(7) Its solubility at air temperature in chemically pure carbon disulphide for the following named materials, or materials similar thereto, shall be at least 99.5 per cent for Residuum or Gilsonite products, 96 per cent for the Bermudez products, 81 per cent for Cuban products, and 66 per cent for Trinidad products.

(8) The solubility of the bitumen at air temperature in 76 per cent Beaumé petroleum naphtha distilling between 140 and 190° F. shall be between 79 and 84 per cent for Residuum, Gilsonite, and Bermudez products, and between 72 and 82 per cent for other products.

(9) It shall show between 9 and 15 per cent fixed carbon.

(10) It shall show an open flash-point of not less than 450° F.

(11) It shall not contain more than 3.7 per cent of paraffine scale, according to the method of determining paraffine scale *given below*. However, a product which contains not more than *4.7 per cent of* paraffine scale will be accepted but at a reduction *in relative price*, and in bid price for additions, of one-half cent

for each gallon in which the paraffine percentage is over 3.7 per cent but not over 4.03 per cent; one cent when the percentage is over 4.03 per cent but not over 4.37 per cent; one and one-half cents when the percentage is over 4.37 per cent, but not over 4.7 per cent. The foregoing percentages are to be determined in the laboratory of the Commission by its employees.

All bituminous material A will be sampled by an engineer of the department, and no such material will be permitted in the work unless it conforms to the above requirements as determined in the laboratory of the Commission by its employees, nor shall any of it be used until it has been accepted by the Commission.

BITUMINOUS MATERIAL T

The bituminous material T shall be a tar having the following characteristics:

(1) The tar shall contain no water and not more than 0.2 per cent of mineral matter or dirt.

(2) It shall be uniform in character, appearance, and viscosity.

(3) It shall not contain over 0.5 per cent of water soluble materials.

(4) It shall have a specific gravity between 1.17 and 1.25 at 25° C.

(5) It shall contain no body that distils at a lower temperature than 170° C., at least 10 per cent by weight of creosote oil having a gravity of not less than 1.03 at 60° F. shall distil between 170° C. and 315° C., and at least 75 per cent by weight of pitch having a melting-point not higher than 165° F. shall remain after all bodies up to 315° C. have been distilled.

(6) On extraction with CS_2 it shall not contain more than 21 per cent free carbon.

(7) A one-half inch roll of the crude material six inches in length, cooled to a temperature of 15° C., shall permit a torsional test of at least three complete turns without breaking or cracking and shall stretch at least three feet, forming at the center a very fine thread before rupture occurs, and at 60° F. should, when doubled into a length of about one foot, bear hitting hard on an iron or stone surface without showing signs of cracking.

Except where otherwise noted, the methods used in testing will be those proposed by the committee on "Bituminous Materials" of the American Society of Civil Engineers. (See page 112).

All bituminous material T will be sampled by an engineer of the Department, and no such material will be permitted in the work unless it conforms to the above requirements, as determined in the laboratory of the Commission by its employees, nor shall any of it be used until it has been accepted by the Commission.

BITUMINOUS MATERIAL A-T

This material shall be a mixture of bituminous material A and *bituminous* material T of these specifications mixed after

being heated and melted separately in proportion of one part by volume of A and five parts of T.

Measures of known capacity shall be used to obtain these proportions as these materials are placed in the heating tank on the highway.

All the ingredients of bituminous material A–T will be sampled by an engineer of the Department, and no such material will be permitted in the work unless it conforms to the above requirements, nor shall any of it be used until it has been accepted by the Commission.

MINERAL BITUMEN

Mineral bitumen shall consist of mineral matter mixed when heated to between 170° F. and 220° F., with 10 per cent of bituminous material when heated to between 300° F. and 400° F. The mineral matter must be clean siliceous sand of varying sizes. It shall be a well-graded sand of which 100 per cent shall pass a No. 6 sieve; between 70 and 85 per cent shall pass a No. 30 sieve; between 40 per cent and 60 per cent shall pass a No. 50 sieve; between 15 per cent and 25 per cent shall pass a No. 80 sieve; between 2 per cent and 4 per cent shall pass a No. 200 sieve. The bituminous material shall be "Bituminous Material A" of the general specifications. A rock asphalt finely and evenly ground containing not less than 10 per cent of pure bitumen, as determined in the laboratory of the Commission by its employees (the balance being clean siliceous sand) will be accepted as a mineral bitumen. Notwithstanding the fact that samples of shipment may pass the laboratory test and the shipment be accepted, if it develops that material is used upon the road which has less than 10 per cent of bitumen it shall be removed and material substituted containing not less than 10 per cent.

All mineral bitumen will be sampled by an engineer of the Department, and no such material will be permitted in the work unless it conforms to the above requirements, nor shall any of it be used until it has been accepted by the Commission.

BITUMINOUS MATERIAL H. O. (HOT OIL)

This material shall be a heavy asphaltic oil meeting the following requirements:

(1) It shall be free from water or decomposition products.

(2) The various hydrocarbons composing it shall be present in homogeneous solution, no oily or granular constituents being present.

(3) The gravity at a temperature of 77° F. shall not be lighter than 15° Beaumé.

(4) When evaporated in the open air at a temperature not exceeding 500° F. until 90 per cent of residue remains, the residue shall not be so hard as to show a penetration less than

millimeters when tested for five seconds at 77° F. with a
2 needle weighted with 100 grams.
5) When evaporated in the open air at a temperature not
eeding 500° F. until 80 per cent of residue remains, the residue
ll not be so soft as to show a penetration more than ten milli-
ers when tested for five seconds as above stated.
6) Twenty (20) grams of it upon being maintained at a
form temperature of 325° F. for five hours in a cylindrical
sel two and one-half inches in diameter by three-fourths
1 high shall not lose less than 3 nor more than 6 per cent in
ght.
7) Twenty (20) grams of it upon being maintained at an
form temperature of 400° F. for five hours as stated above
ll not lose less than 6 nor more than 10 per cent in weight.
character of the residue at 77° F. shall be smooth and nearly
d, but not so hard that it may not be easily dented with the
er, and at this temperature it shall pull to a long thin thread.
8) It shall be soluble in chemically pure carbon disulphide
ir temperature to the extent of 99.5 per cent.
9) It shall be soluble in 76° Beaumé petroleum naphtha,
temperature, to the extent of not less than 82 per cent and not
e than 88 per cent. When 20 cc. of naphtha solution, ob-
ied by treating one gram of the bituminous material with
cc. of cold naphtha, is evaporated upon a glass plate, the
due shall be adhesive and sticky, and not oily.
10) It shall show between 6 and 12 per cent of fixed carbon.
11) It shall show a flashing point (New York State closed
tester) of more than 325° F.
12) It shall not contain more than 3.5 per cent of paraffine
e.
ll asphaltic oil will be sampled by an engineer of the De-
tment, and no such material will be permitted in the work
ess it conforms to the above requirements, nor shall any of
e used until it has been accepted by the Commission.

BITUMINOUS MATERIAL C. O. (COLD OIL)

his material shall be an asphaltic oil meeting the following
uirements:
1) It shall be free from water or decomposition products.
2) The various hydrocarbons composing it shall be present
homogeneous solutions, no oily or granular constituents being
sent.
3) The gravity at a temperature of 77° F. shall not be lighter
n 19° Beaumé.
4) When evaporated in the open air at a temperature not
eeding 500° F. until 65 per cent of residue remains, the
due shall not be so hard as to show a penetration less than
millimeters when tested for five seconds at 77° F. with a
2 needle weighted with 100 grams.

(5) When evaporated in the open air at a temperature not exceeding 500° F. until 55 per cent of residue remains, the residue shall not be so soft as to show a penetration more than 10 millimeters when tested for five seconds as above stated.

(6) Twenty grams of it, upon being maintained at a uniform temperature of 325° F. for five hours, in a cylindrical vessel 2½ inches in diameter by ¾-inch high, shall not lose more than 12 per cent in weight.

(7) Twenty grams of it upon being maintained at a uniform temperature of 400° F. for five hours, as above stated, shall not lose more than 20 per cent in weight.

(8) It shall be soluble in chemically pure carbon disulphide at air temperature to the extent of at least 99.5 per cent.

(9) The bitumen shall be soluble at air temperature in 76° Beaumé naphtha, distilling between 140° and 190° F., to the extent of not less than 87 per cent and not more than 99 per cent. When 20 cc. of a naphtha solution obtained by treating one gram of the bituminous material with 100 cc. of cold naphtha is evaporated upon a glass plate, the residue shall be adhesive and sticky and not oily.

(10) It shall not show more than 10 per cent fixed carbon.

(11) It shall show an open flash-point of not less than 300° F.

(12) It shall not contain more than 3 per cent paraffine scale.

BITUMINOUS MATERIAL L. C. O. (LIGHT COLD OIL)

The material shall be light asphaltic oil meeting the following requirements:

(1) It shall be free from water or decomposition products.

(2) The various hydrocarbons composing it shall be present in homogeneous solution, no oily or granular constituents being present.

(3) The gravity at a temperature of 77° F. shall not be lighter than 25° Beaumé.

(4) When evaporated in the open air at a temperature not exceeding 500° F. until 35 per cent of the residue remains, the residue shall not be so hard as to show a penetration less than 10 millimeters when tested for five seconds at 77° F. with a No. 2 needle weighted with 100 grams.

(5) When evaporated in the open air at a temperature not exceeding 500° F. until 45 per cent of residue remains, the residue shall not be soft enough to show a penetration of more than 10 millimeters when tested for five seconds as above stated.

(6) Twenty grams of it upon being maintained at a uniform temperature of 325° F. for five hours, in a cylindrical vessel 2½ inches in diameter by about ¾-inch high, shall not lose more than 15 per cent in weight.

(7) Twenty grams of it upon being maintained at a uniform temperature of 400° F. for five hours as above stated shall not lose more than 30 per cent in weight.

(8) It shall be soluble in chemically pure carbon disulphide at air temperature to the extent of at least 99.5 per cent.

(9) The bitumen shall be soluble at air temperature in 76° Beaumé naphtha, distilling between 140° and 190° F., to the extent of not less than 87 per cent and not more than 99 per cent. When 20 cc. of a naphtha solution, obtained by treating one gram of the bituminous material with 100 cc. of cold naphtha, is evaporated upon a glass plate, the residue shall be adhesive and sticky and not oily.

(10) It shall not show more than 8 per cent of fixed carbon.

(11) It shall not show an open flash of less than 280° F.

(12) It shall not contain more than 4 per cent of paraffine scale.

BRICK

Paving brick shall be reasonably perfect in shape — shall be ree from marked warping or distortion, and shall be uniform in ize, so as to fit closely together and to make a smooth pavement. All brick shall be homogeneous in texture and free from aminations and seams. All brick shall be evenly burned and horoughly vitrified.

Soft, brittle, cracked, or spalled brick, or brick kiln-marked to height or depth of over $\frac{3}{64}$ parts of an inch will be rejected.

If brick have rounded corners, the radius shall not be greater han $\frac{1}{16}$ part of an inch.

Brick must have not less than two nor more than four vertical ugs or projections not more than $\frac{1}{2}$ inch wide, on one side of ach brick, the total area of all lugs being not more than 3 square nches, so that when laid there shall be a separation between the ricks of at least $\frac{1}{8}$ inch and not more than $\frac{1}{4}$ inch. The imprint, r name of the brick, or maker, if used, shall be by means of ecessed and not by raised letters. The two ends of the brick hall have a semi-circular groove, with a radius of not less than of an inch and not more than $\frac{1}{4}$ of an inch. Grooves shall be so ocated that when the brick are laid together the grooves shall natch perfectly; grooves shall be horizontal when brick is laid n pavement.

All brick shall not be less than $3\frac{1}{4}'' \times 3\frac{3}{4}'' \times 8\frac{1}{2}''$ nor more than $\frac{1}{2}'' \times 4'' \times 9''$ in size.

All brick shall be subject to tests for abrasion and impact, or absorption, according to the standard methods prescribed y the National Brick Manufacturers' Association, as follows:

The Standard Rattler shall be twenty-eight (28) inches in liameter and twenty (20) inches in length, measured inside the attling chamber, the cross-section of which shall be a regular olygon of fourteen sides. There shall be a space of one-fourth f an inch between the staves to provide for the escape of dust nd chips.

The Standard Charge will consist of approximately one thousand ubic inches of the brick to be tested, together with a standard harge of *three hundred* (300) pounds of cast-iron forms composed

of approximately two hundred and fifty-six (256) cast-iron cubes one and one-half inches on a side with square edges and corners, and ten cast-iron blocks two and one-half inches square and four and one-half inches long with slightly rounded edges. Forms that have lost 15 per cent in weight shall be replaced by new forms.

The Standard Test will consist of 1,800 revolutions of a standard rattler with a standard charge as above. The speed of the rattler will not be more than thirty, nor less than twenty-eight, revolutions per minute.

Bricks to be tested will be dried for forty-eight hours continuously at a temperature of from 230° to 250° F. They will then be weighed on scales sensitive to one gram, rattled, as above, reweighed, and immediately immersed in water for a period of forty-eight hours. After soaking and before reweighing the bricks will be wiped free from all surplus water.

The increase in weight, due to absorption, will be calculated in per cents of the dry weight of the brick.

Any brick which loses nineteen (19) per cent or more in the rattler, or increases more than 3½ per cent in weight or less than ½ of 1 per cent in the absorption test, will be rejected.

On grades of five (5%) per cent or over the engineer may, if he deems advisable for the traffic, order the contractor to use special form of brick suitable for steep grades.

Expansion Joint Paving Pitch. This cushion shall be composed of heavy pitch or asphaltum composition, having a melting point of not less than 120° F. nor more than 140° F., filling the allotted space.

BLOCK STONE PAVEMENT

(City of Rochester, N. Y., Specifications, 1911)

Paving blocks shall consist of the best quality of Medina sandstone free from quarry checks or cracks, and shall be quarried from fine-grain live rock, showing a straight and even fracture. The material shall be of uniform quality and texture, free from seams or lines of clay or other substances which, in the opinion of the City Engineer, will be injurious to its use as paving material

Blocks shall measure not less than three (3) nor more than six (6) inches thick, and not less than six (6) nor more than six and one-half (6½) inches deep, and from seven (7) to twelve (12) inches in length. Stones to have parallel sides and ends, and right-angle joints. All roughness in joints of stone to be broken off, so that when set in place they shall have tight joints for a distance of at least two and one-half (2½) inches from the top down. The top to have a smooth even surface, with no projection or depression exceeding one-quarter (¼) inch.

When approved by the City Engineer, paving blocks of the following dimensions may be used:

Three to five inches in width; five inches in depth, with an

allowable variation of one-quarter inch, more or less, in said depth, and seven to twelve inches in length.

Paving blocks as here referred to shall be understood to mean blocks of Medina sandstone, prepared in the usual manner for dressed block paving by nicking and breaking the stone from larger blocks, as is done at the quarries where such blocks are usually prepared, and not made by re-dressing or selecting from common stone paving material.

The stones will be carefully inspected after they are brought on the line of the work, and the blocks which, in quality and dimensions, do not conform strictly to these specifications, will be rejected and must be immediately removed from the line of the work. The contractor will be required to furnish such laborers as may be necessary to aid the inspector in the examination and the culling of the blocks.

The stones brought upon the ground having been carefully and thoroughly inspected, as provided for herein, and all rejected stones removed from the line of the work, the contractor will then be required to pile such stone as may have been approved, neatly, on the front of the sidewalk, and not within three (3) feet of any fire hydrant, and in such manner as will preserve sufficient passageway, on the line of the sidewalks, and also permit of free access from the roadway to each entrance on the line of the street.

SECOND QUALITY BLOCKS

(THE FOLLOWING NOT IN ANY SPECIFICATIONS)

Second quality block, known as pavers, are practically the same material as the first quality block, the only difference being a greater range of size and a less careful top and joint finish. They cost $0.50 per square yard less. These pavers can be furnished under a specification allowing the following range of size and joint width:

(CITY OF CLEVELAND SPECIFICATIONS)

"Common paving stones shall consist of the best quality of Medina sandstone, and shall be not less than three (3) nor more than five (5) inches thick, and not less than seven (7) nor more than eight (8) inches deep, and from eight (8) to thirteen (13) inches long. The stones to have parallel sides and ends, with right-angle joints, all roughness and points of stone to be broken off so that when set in place they shall have tight joints for a distance of at least three inches from the top; the area of the bottom of any stone to be not less than three-quarters ($\frac{3}{4}$) of the area of the top, the top of all stones to have a smooth even surface."

CEMENT

(New York State Specifications, 1911)

General Conditions. All cement shall be subject to rigid inspection and to prescribed tests made at the cement-testing laboratory of the Commission.

Portland cement shall be used and shall be of the brand known by prior use on extensive works to be of the best quality.

Provisions shall be made by the contractor for storing cement in a dry place and delivery shall not be made until the Commission has been notified to inspect the cement and to take samples, for which facilities shall be afforded by the contractor. The contractor shall not use on the work any cement which becomes damaged while stored.

The cement shall be stored so that each shipment and each car lot shall be kept separately.

Cement for which no notification of acceptance or rejection has been received shall be sampled by the engineer immediately upon its arrival at the road. One sample shall be taken from at least every tenth barrel or from the equivalent of the tenth barrel when packed in sacks, each sample will be sufficient to fill a 3-inch cubical box and each lot of samples will be numbered consecutively throughout the progress of the work on each contract and shipped to Albany for test. Not more than one car-load of cement shall be represented by one lot of samples.

These tests will be: first, for fineness; second, for constancy of volume; third, for time of initial set; fourth, for tensile strength; fifth, for composition by chemical tests; sixth, for specific gravity.

The average results of the tests of the different samples shall be the test for tensile strength of any lot. With brands of cement known to be generally uniform, in order to facilitate the work of testing, the samples of car-load lots may be blended in the laboratory and the average results of five briquettes shall be the test.

The results of the tests may be expected in twelve days after shipment of samples.

Cement of each brand shall be required to show uniform and characteristic results in tests.

Cement not satisfactory to the Commission in the seven-day tests will be held awaiting the result of the twenty-eight-day test before acceptance or rejection.

Any cement which has been rejected shall be immediately removed at the expense of the contractor.

The acceptance or rejection will be based on the following requirements.

SPECIFICATIONS FOR PORTLAND CEMENT

This material shall be Portland cement meeting the following *requirements:*

Tensile Strength. Briquettes of neat cement mixed three

›ut in the mold with thumbs and trowel, and kept at
.ture of 65° to 70° F. for one day in moist air and six
ater, shall show an average tensile strength of at least
'ed (500) pounds per square inch.
tes of three parts by weight of standard crushed quartz
one part by weight of cement, mixed in the same
nd kept seven days under the same conditions, shall
average tensile strength of at least one hundred and
o) pounds per square inch.
tes of three parts by weight of standard crushed quartz
›ne part by weight of cement, mixed in the same manner
twenty-eight days under the same conditions, shall
average tensile strength of at least two hundred and
pounds per square inch. The separate samples shall
ncrease in strength in the twenty-eight-day tests over
s secured in the seven-day tests.
.cy of Volume. Pats of neat cement about 3″ × 4″
thick at the center, and tapering to a thin edge; shall
moist air for a period of twenty-four hours.
Tests: Air test. One of these pats is then kept in
normal temperature for twenty-eight days.
est. Another pat is kept in water maintained as near
›ractical for twenty-eight days.
ited Test. A pat is exposed in any convenient way
osphere of steam, above boiling water, in a loosely
sel for five hours.
›ats are observed at intervals and, to satisfactorily
equirements, shall remain firm and hard and show no
stortion, checking, cracking, or disintegration.
Setting. Cement shall develop its initial set in not
50 minutes, and shall develop a hard set in not less
ninutes nor more than 600 minutes; the determination
e with the vicat needle apparatus from pastes of normal
y, as follows:
te is molded upon glass in a conical hard rubber mood
; this cake is set in moist air and a vicat needle with
mm. in diameter and loaded to 300 grams shall be
›n it. When the needle ceases to pass a point 5 mm.
upper surface of the glass plate the initial set has
e.
s. It shall be ground to such fineness that not less
r cent by weight shall pass through a No. 50 standard
500 meshes per square inch, and not less than 92 per
'eight shall pass through a No. 100 standard sieve of
shes per square inch.
Gravity. The specific gravity of the cement after
› a low red heat shall not be less than 3.10; and the
all not show a loss in weight on ignition of more than

l Tests. *The* Commission may cause chemical tests,

or analyses, of cement to be made and may reject any cement which shows any adulteration, or excess of ingredients, which in its judgment would be detrimental to the work.

The cement shall not contain more than 4 per cent of magnesia (MgO), nor more than 0.75 per cent of anhydrous sulphuric acid (SO_3),

Sand. The standard sand used in the tests shall be a crushed quartz sand passing a No. 20 standard sieve of 400 meshes per square inch and shall be retained on a No. 30 standard sieve of 900 meshes per square inch.

CAST-IRON PIPE

Cast-iron pipe shall be light weight and may be second quality, but it shall be free from all defects impairing its strength. The iron must be of good quality, uniform in thickness and of full strength, and the pipe shall be coated with coal pitch varnish mixed with linseed oil to form a firm, tough coating. The joint shall be formed by calking into the hub a gasket of jute or oakum and then filling with mortar formed of equal parts of Portland cement and clean sharp sand.

MESH REINFORCEMENT

Mesh reinforcement shall be placed where called for on the plans or ordered by the engineer. It shall be of medium steel.

If expanded metal is used it shall conform to the above requirements, and the weight per square foot shall be as shown on the standard structure sheet, and any reinforcement shall be of a character that it will distribute the loads evenly.

DEFORMED BARS

Deformed bars shall be placed where called for on the plans or ordered by the engineer. They shall be of medium steel and shall have a deformed cross-section, that is, the various cross-sections must be of different shape or their centers must not lie in the same axis.

CAST IRON

Cast iron shall be of full standard pattern for shapes or forms used, according to drawings or detailed specifications. All cast iron shall be of good gray iron, free from blows, sand holes, or other defects, and shall have a tensile strength of not less than 17,000 pounds per square inch of section.

WROUGHT IRON

Wrought iron shall be tough, fibrous, and uniform in quality and shall be manufactured by approved methods. Steel scrap shall not be used in its manufacture. Finished

ıl shall be clean, smooth, straight, true to shape, of anlike finish and free from defects.

pieces cut from finished material shall show an ultimate strength of not less than 48,000 pounds per square inch, tic limit of not less than 25,000 pounds per square inch, elongation of not less than 20 per cent in 8 inches.

ught-iron test pieces cut from finished material when when heated to a bright, cherry-red, shall endure bending grees around a circle whose diameter is equal to twice ckness of the test piece, without signs of cracking. Test when nicked and broken shall show a fracture not less ɔ per cent fibrous, free from coarse, crystalline spots.

ught iron when welded shall not show signs of red shortness.

STEEL

Steel, except as otherwise provided by these specifications, e made by the acid or basic open-hearth process and shall orm in character; finished material shall be clean, smooth, t, true to shape, of workmanlike finish, and free from de-

Fractures must show a uniform fine grain of a blue, steel-gray ıtirely free from a fiery luster or a blackish cast.

No work shall be put upon any steel at or near the blue ature or between the temperature of boiling water and of ition of hardwood sawdust.

No sharp or unfilleted corners will be allowed in any piece ıl.

Annealing. Crimped stiffeners and buckled plates need annealed. All other steel that has been bent cold or ly heated and all forgings must be wholly annealed; ex- ı may be made in unimportant cases and then only upon ı permission from the Commission.

Tests of steel that is to be annealed shall be made after ng, or strips cut from such steel shall be annealed at the ime, before testing.

Tests of Medium Steel. Test pieces cut from finished al shall show an ultimate strength of not less than sixty nd (60,000) pounds per square inch and not more than ight thousand (68,000) pounds per square inch, an elastic f not less than thirty-five thousand (35,00) pounds per inch, an elongation of not less than twenty-two (22) per eight (8) inches, and a reduction of area at the fracture less than forty (40) per cent.

Medium steel shall not contain more than five one- dths (5–100) of one per cent of sulphur.

Acid steel shall not contain more than eight one-hun- s (8–100) of one per cent, and basic steel shall not contain han four one-hundredths (4–100) of one per cent of phos-

Medium steel shall endure bending cold or after quenching

from a red heat in water at 80° F., 180° around a circle whose diameter is equal to the thickness of the test piece, without signs of cracking.

(11) **Tests for Soft Steel.** Test pieces cut from finished material shall show an ultimate strength of not less than fifty thousand (50,000) pounds per square inch and not more than fifty-eight thousand (58,000) pounds per square inch, an elastic limit of not less than thirty thousand (30,000) pounds per square inch, an elongation of not less than twenty-eight per cent in eight inches, and a reduction in area at the fracture of not less than fifty (50) per cent.

(12) Soft steel shall not contain more than four one-hundredths (4–100) of one per cent of sulphur.

(13) Acid steel shall not contain more than six one-hundredths (6–100) of one per cent, and basic steel shall not contain more than four one-hundredths (4–100) of one per cent of phosphorus.

(14) Soft steel shall endure bending flat upon itself without signs of cracking, when cold, or after quenching, from a red heat, in water at eighty (80) degrees F.

VITRIFIED PIPE

Vitrified pipe shall be double strength salt-glazed vitrified stoneware sewer pipe of the first quality. The item will include the furnishing, delivering, handling, laying, and cementing of joints; also the operations of excavating the trench, bracing, sheeting, or otherwise supporting the sides, grading and preparing the bottom, back-filling and compacting to the original surface, and the removal of all surplus material.

POROUS TILE

Where called for on the plans, or ordered by the engineer, porous tile shall be laid true to line and grade, and firmly bedded in clean cinders, gravel, or crushed stone. The tile must be whole and free from cracks and other defects, and must be satisfactory to the engineer.

TIMBER

(WASHINGTON STATE SPECIFICATIONS)

Quality of Timber and Plank. All timber and plank in culverts, trestlework, bridge abutments, and pile bridges shall be of good quality, of such kinds as the highway commissioner may direct, free from shakes, wanes, black and unsound knots, and all descriptions of decay, and shall be measured by the thousand feet, board measure; the price shall be understood to cover the expense of all labor (including all necessary digging and filling at the ends of bridges where grading is done before bridges are put in) and materials, pins, or treenails required in the performance of the work.

All timber structures shall be built in conformity with plans to be furnished by the engineer.

Piles and Pile-driving. Piles, whether used in foundations, trestlework, or pile bridges, shall be of good, sound quality of such timber as the highway commissioner may accept, not less than ten inches in diameter at the smaller end and of such lengths as the engineer may require. They shall be measured by the lineal foot after they are driven and cut off to receive the superstructure, and the price per lineal foot shall be understood to cover the expense of driving, cutting off, removing the bark from the part above the ground, and all other labor and material required in the performance of the work; but that portion of each pile cut off shall be estimated and paid for by the lineal foot as "piling cut off." Piles shall be driven of such lengths and to such depths as the engineer may require. All piles shall be capped during the driving to prevent brooming.

CLEARING AND GRUBBING

Clearing. The right-of-way must be cleared to the width of —— feet on each side of the center line, or as shall be designated by the engineer; all trees, brush, and other vegetable matter within the space designated to be cut down, and the same together with all other logs, brushwood, and fences already down, shall be burned or removed from the grounds, as the engineer may direct, so as not to injure the adjoining lands or to obstruct the line of the fences along the boundaries of the said right-of-way. When the embankments exceed two feet in height it will be required to cut the trees, brush, and stumps close to the ground.

Light clearing shall include the removal of all standing trees of a size up to one foot in diameter, together with all other logs, brush, and other vegetable matter already down or lying loose on the ground.

Heavy clearing shall include the removal of all standing trees over one foot in diameter, together with all other logs, brush, and other vegetable matter already down or lying loose on the ground.

Grubbing. From the space required for the roadbed and necessary slopes and side drains, and whatever additional space may be required by the engineer, except where the excavations are three feet or more in depth, or embankments two feet or more in height, all stumps and other wood or vegetable matter embedded in the ground shall be grubbed up, and removed or disposed of as the engineer may direct, and only the area so grubbed shall be estimated.

EXCAVATION

Under the head of excavation shall be included all excavations required for the formation of the roadbed, the digging of all ditches, cutting new channels for streams, preparing foundations, the altering of all highway or private roads and all excavations

in any way connected with or incidental to the construction of the road, and the expense of hauling and depositing same in embankments wherever required.

Embankments. Under the head of embankments shall be included all embankments for any of the purposes mentioned not formed from excavations taken from the prism of the road or other necessary excavations.

All grading shall be done and estimated by the cubic yard, measured in the excavation, except material borrowed for embankment, which shall be measured in embankment, and shall be comprised under heads, viz.:

Earth, Hard-pan, Loose Rock, Solid Rock, Shell Rock, and Solid Rock Borrow.

Earth. Earth will include clay, sand, loam, gravel, and all hard material that can, in the opinion of the chief engineer, be reasonably plowed, and all earthy matter or earth containing loose stones or boulders intermixed, and all other material that does not come under the classification of hard-pan, loose rock, solid rock, shell rock, and solid rock borrow.

Hard-pan. Hard-pan will include material, not loose or solid rock, that cannot, in the opinion of the chief engineer, be reasonably plowed on account of its own inherent hardness.

Loose Rock. Loose rock will include all stone and detached rock, found in separate masses, containing not less than one cubic foot, nor more than one-half cubic yard, and all slate or other rock, soft or loose enough to be removed without blasting, although blasting may occasionally be resorted to.

Solid Rock. Solid rock will include all rock in place, and boulders measuring one-half cubic yard and upwards, in removing which it is necessary to resort to drilling and blasting.

Shell-rock Excavation. Shell-rock excavation will include all deposits composed entirely of rock in masses of less than one cubic foot which have broken off from the cliffs above the roadbed, but will only be estimated when in large deposits.

Solid Rock Borrow. Solid rock borrow shall consist of solid rock, according to above classification, excavated outside of the regular cross-sections of the cuts for the roadbed, and placed and measured in embankment.

EXCAVATION

(New York State Specifications, 1911)

Excavation will include the grading of the roadway, ditches, and side slopes the entire length of the highway to conform to the width, lines, and grades shown on the plans or as fixed from time to time by the Commission, also the digging of foundation pits for all structures, the cleaning out of waterways and old culverts, the digging of all necessary outlet ditches, and the grading of all highway intersections. Unless such work is ordered by the Commission in writing, no allowance will be made for

xtra excavation beyond or below the widths, lines, and grades hown on the plans or as fixed by the Commission. All ditches nust be dug before any rolling will be allowed.

All muck, quicksand, soft clay, and spongy material which vill not consolidate under the roller shall be removed to a depth o be determined by the engineer, and the space thus made shall e filled with such material as the engineer may direct.

The term "rock" as used in these specifications will be interreted to mean ledge rock or boulders of more than six cubic eet volume. Boulders of less than six cubic feet volume, and soft r disintegrated rock which can be removed with a pick and hovel, will not be classified or paid for as rock.

The contractor shall excavate such drainage ditches as the ngineer may direct.

Such excavated material as may be fit for the purpose and as nay be necessary shall be used to fill in those parts of the oadway which are below the aforesaid grades, or which have ecome so by the removal of rock or improper material, in the nanner hereinafter provided; and the item of excavation is to nclude the proper placing of such excavated material as filling n embankment, and the removal from the work of all such as is ot so utilized. When the excavated material fit for filling is nsufficient in quantity to regulate the road, the contractor hall obtain from borrow pits, or other sources approved by the ngineer, all additional material necessary, and place it where equired. If the haul on any material required for embankment exceeds 2,000 feet it will be classified as overhaul; and ayment shall be based on a rate per cubic yard for each one undred (100) linear feet greater than two thousand (2,000) feet hat the material is so hauled.

Back-filling for culverts, concrete retaining walls, and reinforced concrete retaining walls will be classified as excavation.

All surplus excavation and waste material shall be used to widen embankments, or flatten side slopes; or it shall be deposited in such other places and for such purposes as the engineer may direct.

The contractor will not be allowed to put on the margin of the road, in unsightly piles, rock or boulders excavated in excess of what can be used in embankment. Such excavation should be placed where directed by the engineer.

All finished surfaces and slopes shall be trimmed and left in a neat condition in conformity to the lines and in accordance with the directions given by the engineer.

For the purpose of ascertaining additions or deductions the volume of all excavated material which will enter into the final computation of the quantities will be that occupied by it before its removal, and will be determined by measurements taken before and after its removal. The maximum limits of such volume must not exceed those defined upon the plans or fixed by the Commission.

Where the preliminary quantities would indicate that the material to be excavated, fit for filling, is insufficient to form embankments, the excavation shall all be made for a distance of 4,000 lineal feet on either side of the place where the deficiency appears to occur. Such excavated material shall be placed in the embankments before borrowing will be authorized. After the excavation has been made as aforesaid, and the material obtained therefrom which is suitable placed in the embankment, and a deficiency still remains, then excavation from borrow pits will be authorized, measured, and included in the final computation of this item. No allowance will, however, be made for borrowed material when there is an equivalent waste of the excavated material from the roadbed within 4,000 lineal feet of the place of deposit. Where borrow pits are authorized by the engineer within the limits of the roadway, the same will be staked out by the engineer, and must be dressed up on completion to a uniform width, grade, and slope of banks similar to that required for the standard section of the roadway.

Filling or Embankment. Embankment shall be formed of earth or other materials satisfactory to the engineer and must be free from vegetable matter or refuse of any kind. If formed of stone, as may be the case where material from rock cut is used, it shall be carefully placed and all spaces completely filled with sand, earth, or gravel so as to form a solid embankment; the stone shall not be placed nearer than six inches to the bottom course or surface of shoulders.

Where the filling required is less than two feet in depth the old surface shall be broken up and all sod and vegetable matter removed from the area included between two parallel lines, two feet outside of the edge of the pavement, on each side. Where the angle of the slope of the original surface, measured perpendicular to the center line, is greater than 30 degrees from the horizontal, the original surface shall be thoroughly broken up for the entire width of the embankment. No sod will be allowed to be placed in embankments nearer than four feet from the edge of the pavement.

Embankment shall be constructed in successive horizontal layers not exceeding twelve inches in thickness. Each layer shall extend across the entire fill, and shall be flooded with water when so directed, and rolled to the satisfaction of the engineer. All side slopes shall be built as shown on the plans, unless modified in writing by the division engineer.

PREPARING SUBGRADE

After the surface of the subgrade has been properly shaped, and before any broken stone or other material is put on, it shall be thoroughly rolled and compacted, water puddling being resorted to in case the soil requires it. This rolling shall be done *with a self-propelled* roller weighing approximately ten tons. The *roller must be of* a type approved by the Commission. All

hollows and depressions which develop during the rolling shall be filled with material acceptable to the engineer and the subgrade shall again be rolled. This process of filling and rolling shall be repeated until no depressions develop. The shoulders also shall be rolled in the same manner, but in places where the character of the material makes the use of a ten-ton roller impracticable, the division engineer may permit a lighter roller to be used.

SUB-BASE COURSE

Wherever soft clay, silt, quicksand, or other unstable material is encountered in forming the subgrade, the same shall be formed to the shape indicated by the engineer at a depth below the base of the macadam to allow for the placing of a sub-base course of ——— ——— as a foundation upon which to construct the bottom course.

Under no circumstances shall sub-base course be placed on any subgrade which is not dry.[1]

Where field or quarry stone is used to form sub-base course, the fragments shall be roughly placed by hand in order to bring the same in as close contact as possible, and to provide the least amount of voids.

The sub-base course shall then be rolled as described for the bottom course of macadam, and thereafter covered with two inches of gravel or stone chips and again rolled until the stone are bound together and do not weave ahead of the roller, and hollows or depressions found in rolling shall be filled with gravel or stone chips and the surface made to conform with the typical section shown on the plans.

In limited areas where the use of a roller would be impracticable heavy rammers may be used to properly consolidate the sub-base.

Where gravel or tailings from the crusher are used for forming a sub-base course the same shall be rolled and treated in a similar manner.

The location of the sub-base will be as shown on the plans or indicated by the division engineer in writing.

The bottom course shall not be placed on any subgrade until the subgrade has been accepted by the engineer.

The item of sub-base will include the material, placing same, filling, rolling, and all necessary work connected therewith.

SUB-BASE BOTTOM COURSE

After the subgrade has been prepared and has been accepted by the engineer, a layer of any approved quality of field stone, quarry stone, or clean stone from stream channels shall then be spread upon the subgrade to such a depth that it shall have when thoroughly consolidated the required thickness.

The stone shall be roughly placed by hand, with the larger

[1] See page 288, Construction.

stone in the center of the course. It shall then be rolled w ten-ton roller, after which any projecting, bridged, or loose s shall be broken by hand. A filler of approved clean gr stone chips, or crushed stone of sufficient quantity to compl fill all voids and depressions shall then be spread, after w the rolling shall continue until the entire course is thorou consolidated, and conforms with the typical section show the plans.

When called for on the plans, or ordered by the engi lateral drains of loose stone shall be constructed every 100 on each side and staggered, draining into ditches.

No top course shall be placed on sub-base bottom co until the sub-base bottom course has been accepted by th gineer.

The item of sub-base bottom course will include the st filler, manipulation, and all necessary work connected there

STONE MACADAM BOTTOM COURSE

After the subgrade has been prepared and has been acce by the engineer, a layer of broken stone of the approved and quality for bottom course shall be spread evenly over such depth that it shall have, when rolled, the required tl ness.[1] The depth of the loose stone shall be gauged by la upon the subgrade cubical blocks of wood of the proper size spreading the stone evenly to conform to them.

The roller shall be run along the edge of the stone back and forward several times on each side before rolling the ce Before putting on the filler the course shall be rolled until stone does not creep or weave ahead of the roller. In no shall the screenings or sand for filler be dumped in mass u the crushed stone, but they shall be spread uniformly over surface from wagons or from piles that have been placed on shoulders. It shall then be swept in with a rattan or steel br and rolled dry. This process shall be continued until no m will go in dry, when the surface shall, if required by the engi be sprinkled to more effectually fill the voids. No filler sha left on the surface, and surface of bottom-course stone shal swept clean before covering with top course. Only such te ing as is necessary for the distributing of the materials wil allowed on the bottom course. Any irregularities or depressi the result of settlement, rolling, or teaming, if slight, shal made good with broken stone of the same size used in the bot course, otherwise the stone shall be removed and the subg regraded and rolled. Such removal and restoring of the su shall be made at the expense of the contractor. Screenings s *not* be used in leveling up irregularities or depressions.

[1] *It is better to* specify the amount of stone by weight; the approximate rat *loose to rolled depths* are given on page 234.

SCREENED GRAVEL BOTTOM COURSE

avel shall be used for bottom course in place of stone when ecified. The size of the gravel shall be the same as specified one, and the work of preparing and rolling the gravel bottom e shall be the same as for the stone-bottom course, except if necessary to properly consolidate the gravel, 5 per cent y, pulverized loam or clay may be incorporated with the l if ordered by the division engineer, and the course kled if necessary for proper consolidation.

SUBGRADE AS BOTTOM COURSE

be used only when subgrade is of gravel which may be iently compacted, as described below, to render unnecessary tom course.

e roadbed shall be shaped to conform, when compacted, the top of the bottom course as shown on the plans. When-gravel is encountered which is free from loam or clay one-half in depth of clean, dry loam, dust, or clay thoroughly pul-ed, shall be added to the graded and shaped roadbed and ughly mixed with the top three inches of gravel, after which ll be sprinkled and rolled with a self-propelled road-roller hing at least ten tons, until additional rolling ceases to er compact the roadbed. Any irregularities or depressions esult of settlement or rolling, if slight, shall be made good gravel thoroughly mixed with 10 per cent of dry pul-ed clean loam or clay and rolled.

TOP COURSES

ne Macadam Top Course — Puddled. The top course of shall be spread on the bottom course to such depth that it have, when completed, the required thickness.[1] Blocks od of proper size shall be used to gauge the depth of the stone; care must be taken to preserve the grade and crown, to prevent a wavy surface; and all irregularities and de-ions shall be made up with stone the size of the top course . After the surface is true to line, grade, and cross-section rolled until the stone ceases to wave in front of the roller, ll be covered with a light coating of screenings, spread on rolled and swept in. The spreading, sweeping, and rolling screenings shall continue until no more will go in dry, after h the road shall be sprinkled until saturated, the sprinkler followed by the roller. More screening shall be added cessary, and the sweeping, sprinkling, and rolling shall nue until a grout has been formed of the screenings, stone and water that shall fill all voids and shall form a wave before heels of the roller. The road shall be puddled as many times y be necessary to secure satisfactory results.

is better to specify the amount of stone by weight; the ratio of loose to rolled *given on page 234*.

After the wave of grout has been produced over the wh tion of the road this portion of the road shall be left after which it shall be opened to travel, and thereafter s thoroughly sprinkled once each day in dry weather for a p thirty days. Enough screenings shall be spread on top macadam to leave a wearing surface at least three-eigl an inch thick. This wearing surface shall be maintained and i if necessary until the whole road has been accepted.

Stone Macadam Top Course — Puddled and Oiled course for oiled macadam shall be constructed as for p macadam. After the road has been puddled as stated a surface has become dry, it shall be swept so as to expo clean the surface of the top course of stone. The sweepin continue until the voids are exposed to a depth of one-ha care being taken not to disturb the stone. The road shall then be left free from traffic until the top course ha oughly dried out, when it shall be swept free from dust a voids cleaned to the depth of one-half inch without dist the top course stone, after which bituminous material *H.* (be evenly applied to the road surface at a temperature of no than 400° F. or less than 300° F. The amount of oil applied shall be 0.5 gallon for each square yard, and th perature of the air when application is made shall not b than 70° F. Immediately after the application of the oil, quarters of an inch in depth, of perfectly dry top-course ings, free from dust, shall be evenly spread over the road and rolled in with a self-propelled road-roller until an abs firm and smooth surface results, conforming with the p longitudinal and transverse section. The roadway sha be evenly covered with one-quarter of an inch in depth o screenings and thrown open for traffic.

When a machine is used in applying this oil it must such construction that the amount to be applied may be req and spread on the road in a thin uniform sheet.

Stone Macadam Top Course — Bituminous Binder — G [1] No. 2 stone shall be evenly spread upon the bottom using three-quarters of a cubic foot, loose measure, fo square yard of surface. Next there shall be evenly spread 3 stone (care being taken not to disturb the No. 2 stone) t a depth that the whole course shall have, when complet required thickness. Blocks of wood of proper size shall l to gauge the depth of the loose stone.[2] Care must be ta preserve the grade and crown and prevent a wavy surfac wherever irregularities or depressions occur, the top must be loosened up and the No. 3 stone added to take o irregularities and depressions.

[1] The author's experience has indicated that there is no necessity for this No. 2 stone, provided the excess filler is broomed off the bottom course. plification of method results in a lower cost.

[2] *It is better to specify the amount of stone by weight.*

Note. *Bituminous* material (A) should not be applied when the air tem *is less than* 50° F., and the stone must be perfectly dry.

The course shall be rolled with a self-propelled roller weighing at least ten tons, until the surface is firm and compact; after which one and one-quarter gallons of bituminous material *A*, heated to a temperature of 400° F., shall be evenly spread over each square yard of surface by the use of fan-spout sprinkling pots. Immediately thereafter, one-half of a cubic foot of No. 2 stone, per square yard, shall be evenly spread upon the surface to fill the voids, and rolled until no more can be forced into the course. All loose material shall then be swept off. Next four-tenths of a gallon of the bituminous material, heated to a temperature of 400° F., shall be evenly spread over each square yard of surface; upon this shall immediately be spread three-eighths of a cubic foot of dry dustless screenings for each square yard of surface, and the rolling be continued until a firm, smooth surface results, conforming with the plans in longitudinal and transverse section. This wearing surface shall be maintained and renewed, if necessary, until the entire work has been accepted, except that the screenings used in renewing the wearing course need not be dustless, and if more than one renewal is required stone dust will be permitted for subsequent renewals.

For additions or deductions the unit of measure for bituminous material will be the gallon measured at a temperature of 60° F.

STONE MACADAM TOP COURSE — BITUMINOUS BINDER — MIXED

Upon the bottom course there shall be deposited a top course which shall have, when completed, the required thickness. This course shall be composed of top-course stone (65 per cent of No. 3 size, 25 per cent of No. 2 size, and 10 per cent of dry dustless screenings) mixed with bituminous material in the proportion of one cubic yard of stone, measured loose, to fourteen gallons of bituminous material *A*, measured at a temperature of 400° F.

The top-course stone shall be warm and dry, and the bituminous material shall be heated to a temperature of 400° F. when added to the stone. The material shall be mixed until the stone is thoroughly and evenly coated. The mixing shall be done either by hand, on water-tight mixing board or by mechanical mixer of an approved type, after which the material shall, while hot (250° F.), be spread upon the bottom course by the use of shovels and raked to a uniform surface, and in no case shall any of the material be dumped in mass upon the bottom course, either from wheelbarrows or wagons. Blocks of wood of proper size shall be used to gauge the depth of the loose material, care being taken to preserve the grade and crown; also to prevent a wavy surface. One-quarter of a cubic foot of dry dustless screenings shall then be evenly spread over each square yard of surface. The course shall then be rolled with a self-propelled roller of not less than five tons' weight until firm and smooth and no more of the screenings can be forced in. All loose material shall then be

swept off and four-tenths of a gallon of the specified l
material heated to a temperature of 400° F. shall be ev
over each square yard of surface, by the use of fan-sp
ling pots; immediately thereafter shall be spread one
foot of dry, dustless screenings, over each square yard
and the course rerolled until a firm and smooth surf
conforming with the plans in longitudinal and transve
This wearing surface shall be maintained and renewe
sary, until the entire work shall have been accepted, e
screenings used in renewing the wearing course need n
less, and if more than one renewal is required stone d
permitted for subsequent renewals.

For additions or deductions the unit of measure fo
minous material will be the gallon measured at a tem
60° F. and for the stone the cubic yard measured loos

*SCREENED GRAVEL TOP COURSE — BITU BINDER — GROUTED

No. 2 gravel shall be evenly spread upon the bott
using three-quarters of a cubic foot, loose measure
square yard of surface. Next there shall be evenly
No. 3 gravel (care being taken not to disturb the No.
to such a depth that the whole course shall have, v
pleted, the required thickness. Blocks of wood of p
shall be used to gauge the depth of the loose mater
must be taken to preserve the grade and crown and
wavy surface.

One and one-quarter gallons of bituminous material
to a temperature of 400° F., shall then be evenly spread
square yard of surface by the use of fan-spout sprinl
Immediately thereafter, one-half of a cubic foot of No
per square yard, shall be evenly spread upon the sur
the voids, and be rolled with a self-propelled roller w
least ten tons, until the surface is firm and compact an
can be forced into the course. All loose material sha
swept off, and wherever irregularities or depressions
top course must be loosened up and No. 3 gravel, and
amount of bituminous material *A* added to take out s
larities and depressions. Next four-tenths of a gall
bituminous material, heated to a temperature of 40
be evenly spread over each square yard of surface;
shall immediately be spread three-eighths of a cubic f
dustless gravel screenings for each square yard of su
the rolling be continued until a firm, smooth surfa
conforming with the plans in longitudinal and trans
tions. This wearing surface shall be maintained and r
necessary, until the entire work has been accepted, e
the screenings used in renewing the wearing course ne

*NOTE.— Gravel Bituminous Macadams have not been satisfactor

dustless, and if more than one renewal is required, dust or sand will be permitted for subsequent renewals.

For additions or deductions the unit of measure for the bituminous material will be the gallon measured at a temperature of of 60° F.

SCREENED GRAVEL TOP COURSE — BITUMINOUS BINDER — MIXED

Upon the bottom course there shall be deposited a top course which shall be three inches thick when completed. It shall be composed of top-course gravel (65 per cent of No. 3 size, 25 per cent of No. 2 size, and 10 per cent of dry gravel screenings free from dust) mixed with bituminous material in the proportion of one cubic yard of gravel, measured loose, to seventeen gallons of bituminous material *A* measured at a temperature of 400° F.

The division engineer may authorize a slight variation in the proportion of the classes of gravel in order to better fill the voids. The top-course gravel shall be warm and dry and the bituminous material heated to a temperature of 400° F. when added to the tone. The mode of procedure from this point on shall be the same as in the case of top course for bituminous macadam of stone, mixed; substituting the corresponding classes of gravel for those of stone.

TOP COURSE FOR MINERAL BITUMEN

Upon the bottom course there shall be deposited a top course which shall have when completed the required thickness. Wood blocks of the proper size shall be used to gauge the depth of the stone, care being taken to preserve grade and crown, also to prevent a wavy surface.

After the stone is evenly spread to the required thickness, it shall be rolled sufficiently to compact it slightly and make the surface smooth and uniform.

*——— pounds per square yard of the mineral bitumen shall then be spread on the stone by the use of shovels and raked to a uniform thickness. When not over 100 lineal feet of the mineral bitumen has been spread, it shall be rolled with an asphalt roller sufficiently to fill the voids in the stone. The rolling shall begin at the edges and work to the center, care being taken to prevent the bitumen adhering to the roller. *——— pounds per square yard of mineral bitumen shall then be spread in the same manner to a uniform thickness, after which it shall be rerolled and the road closed to traffic for two days during which time it shall be slightly rolled. None of the completed first layer of mineral bitumen shall be left overnight uncovered by the second layer.

A ten-ton self-propelled roller may be substituted for the

* See page 78, Chapter V.

asphalt roller under such conditions and requirements as the division engineer may prescribe.

The contractor shall furnish satisfactory scales for weighing each wagon-load of mineral bitumen used, and all weighing shall be checked by a representative of the State Department of Highways.

APPLICATIONS OF BITUMENS

Specifications for Applying Bituminous Material H.O. (Hot Oils).

The oil shall be of a heavy grade fulfilling all requirements for bituminous material *H.O.*

The road to be treated should be carefully swept until it is thoroughly clean and no screenings, dust, or foreign matter remains upon the surface. The greatest care should be exercised in doing this work not to displace the stone of the top course.

Three-quarters of a cubic foot of No. 2 stone shall then be spread uniformly over each square yard of surface.

The oil shall then be evenly applied to the road surface at a temperature of not more than 400° F., or less than 300° F.

One-half of a cubic foot of screenings shall then be spread uniformly over each square yard of surface. The roadway shall then be rolled and thrown open to traffic.

The machine or apparatus used in applying this oil must be of such construction that the amount to be applied may be regulated and spread on the road in a thin uniform sheet.

The roadbed, when the oil is applied, must be absolutely dry, and oil must not be applied when temperature of the air is below 70° F.

The amount to be applied shall be 0.5 gallon per square yard.

Specifications for applying Bituminous Material C.O. (Cold Oil).

Oil meeting the requirements specified under *C.O.* shall be applied uniformly to the road surface immediately after it has been carefully swept until the top course of stones is exposed and thoroughly cleaned and no dust or foreign matter remains upon the surface. The greatest care shall be exercised in doing the sweeping not to displace the stones of the top course.

The amount of oil to be applied shall be* ——— gallons per square yard.

The machine used in applying this oil shall be of such construction that the amount to be applied can be regulated and spread on the road to form a thin sheet.

The oil shall be delivered in tank cars which are provided with proper steam coils, and the contractor will be required to attach thereto a small boiler by means of which the temperature of the oil can be raised to at least 150° F. in the tank car. After the oil has been transferred to the machine for applying it shall be transported to the road as soon as possible and before the

* See page 74, Chapter V.

temperature has been materially lowered. At the option of the engineer the heating of the oil by steam may be omitted if the temperature is above 70° F.

The contractor shall apply oil to one-half of the road at a time, leaving the other half of the road and shoulder free and open to traffic during the process of oiling. The portion oiled shall then be covered and thrown open to traffic, after which the balance of the road shall be oiled and covered. The full width of the macadam shall be covered in the two applications.

The contractor shall erect and maintain signs at the nearest cross-road on each side of the oiling warning the traveling public that the road is being oiled and that they travel it at their own risk.

The cover shall consist of an approved grade of iron-ore tailings, gravel, screenings from which the dust has been removed, three-quarter stone with sand or gravel for a blotter, as specified and called for in the item of quantities. The cover shall be delivered in piles along the road approximately 1,000 feet apart, these piles to be so placed that they are not dangerous to the traffic. In applying the cover the material shall be loaded into a spreader wagon* designed so that the cover can be applied uniformly and of an even thickness on the roadbed. The amount, per square yard, of cover to be applied shall be determined by the engineer. A portion of the cover shall be reserved, and the contractor will be required from time to time to rescreen such portions of the roadway as become sticky and show a tendency to pick up. The contractor will be required to patch with oil and cover those places in the road which pick up under the traffic, and he shall leave an even, smooth surface on the job he has completed. Particular care shall be taken so as not to leave a ragged and bad edge.

In case three-quarter stone is specified for cover and the road requires a certain amount of repairing, the ruts shall be cleaned out thoroughly and, after the oil has been applied, completely filled with three-quarter stone or stone that will pass a 1¼-inch ring and be retained on a ⅝-inch ring. The cover of three-quarter stone shall be rolled with a light roller, weighing at least five tons, after which it shall be thoroughly screened with screenings or a fine grade of gravel or sand, and again rolled until it is thoroughly hard and smooth.

The work shall be cleaned up and left in a tidy and workmanlike manner.

Payment for applying oil will be made on the basis of the square yard, and shall include the sweeping and preparing of the roadbed, the unloading, hauling, application of the oil, and the applying of the necessary cover; also trimming up and removal of all surplus material.

The payment of cover will be made at the price bid per cubic yard or ton delivered on the road in piles, as specified.

* NOTE.— See page 235, Chapter X.

SPECIFICATIONS FOR APPLYING BITUMINOUS MATERIAL L.C.O. (Light Cold Oil)

Oil meeting the requirements specified under *L.C.O.* shall be applied uniformly to the road surface immediately after it has been swept sufficiently to remove any excessive dust or foreign matter.

The amount of oil to be applied shall be* ——— gallons per square yard.

The machine used in applying this oil shall be of such construction that the amount to be applied can be regulated and spread on the road to form a thin sheet.

The oil shall be delivered in tank cars.

The contractor shall apply the oil to one-half of the road at a time, leaving the other half of the road and shoulder free and open to traffic during the process of oiling. The portion oiled shall then be covered by sweeping back the material previously removed from such portion, and thrown open to traffic. The other half of the road shall then be treated in the same manner.

The contractor shall erect and maintain signs at the nearest cross-road on each side of the oiling, warning the traveling public that the road is being oiled and that they travel it at their own risk.

The work shall be cleaned up and left in a tidy and workmanlike manner.

Payment for applying the oil shall be by the square yard and shall include all sweeping, the unloading and hauling of the oil, and its application.

CONCRETE

Concrete, of the class specified, shall be used in such places and in such forms and such dimensions as may be shown on the plans, or as directed by the engineer.

When the conditions make it desirable to reinforce concrete by the use of embedded steel or iron, the details will be shown on the plans.

Concrete shall be classified as follows: first-class, second-class, third-class.

First-class concrete shall be made of one part Portland cement, two parts clean sand or crusher dust, resulting from the breaking of hard trap, hard sandstone, granite, or gneiss, and four parts of crushed stone, all measured in loose bulk, in boxes or forms of known capacity satisfactory to the engineer.

Crushed stone for first-class concrete shall be trap, granite, or gneiss, satisfactory to the Commission.

Second-class concrete shall be made of one part Portland cement, two and one-half parts of clean approved sand or crusher dust, and five parts of crushed stone or screened washed gravel, all measured in loose bulk in boxes or forms of known capacity satisfactory to the engineer.

* NOTE.—See page 74, Chapter V.

Third-class concrete shall be made of one part Portland cement, three parts of clean approved sand or crusher dust, and six parts of crushed stone, all measured in loose bulk as aforesaid. The substitution of gravel in stone for concrete will not be permitted except in special cases under such conditions and requirements as the Commission may prescribe.

Boulders and fragments of rock may be embedded in third-class concrete. Each stone before being embedded or placed shall be thoroughly washed and soaked, to free it from all dirt. Stones embedded in concrete shall be at least three inches apart at all points, and no stones shall be placed within two inches of the finished exposed surfaces or edges of the concrete. Stones shall be laid on their largest bed and worked down into the concrete so as to exclude the air from any pockets in the lower surface of the stone.

Stone for concrete shall be of an approved kind and quality of rock and shall be free from soil, mud, and dust. Soft stone shall not be used in making concrete. Crushed stone for first-class concrete shall be of the No. 2 size; for the second-class shall be of the No. 2 size mixed with the No. 3 size, if required; and for third-class concrete shall be of the No. 2 or the No. 3 size.

The proportion of mortar which is to form the matrix of the concrete may be varied slightly by the engineer if necessary in order that it shall exceed the natural voids of the loose aggregate. This proportion shall be used until a change in the character of the aggregate may require a slight variation in the proportion of mortar.

Sand, the particles of which shall not be greater than one-eighth inch in size, shall be clean, sharp, and not excessively fine, and shall be screened if required. Crusher dust screened to reject all particles over one-quarter inch in diameter may be used as a substitute for an equal bulk of sand. Shale sand or shale dust shall not be used.

The following methods for hand-mixing shall be followed:

The sand and cement shall be thoroughly mixed dry. Enough water shall then be added to make a plastic mortar. After the mortar has been brought to the proper consistency, the broken stone or gravel, having been previously drenched with water, shall be added, and the whole thoroughly mixed.

The mixing shall be done upon proper water-tight platforms and never on the ground. The mass shall be turned at least six times on the platform and until each particle of stone or gravel is entirely coated with mortar and the mass of a uniform consistency and color. After the materials are wet the work shall proceed rapidly until the concrete is in place and is rammed until the water flushes to the surface and all the voids entirely filled with mortar.

The quantity of water to be used in making concrete will be determined by the engineer, but a wet and plastic mixture, one that quakes under the blows of the rammer, will be required.

All mortar and concrete shall be used while fresh and before it has taken an initial set. Any mortar or concrete that has taken an initial set shall be removed from the mixing boards or receptacle and not used in the work. No retempering of mortar or concrete will be allowed.

Concrete shall be deposited in layers not exceeding six inches in thickness before ramming. In joining new concrete to old or to a concrete that has already set, precaution shall be taken to secure a perfect bonding by cleaning, washing, and grouting with neat cement mortar the work already in place. In order to bond the successive courses, horizontal channels running lengthwise of the wall at least two inches deep and four inches wide shall be formed at the top of the upper layer of each day's work, and at such other levels as work is interrupted, until the concrete has taken its initial set.

In any given layer the separate batches shall follow each other so closely that each one shall be placed and compacted before the preceding one has set, so there shall be no line of separation between the batches.

After the concrete has begun to set, it shall not be walked upon in less than twelve hours.

The operation of compacting the concrete shall be conducted so as to form a compact, dense, impervious, artificial stone. The ramming shall be so thorough as to perfectly compact the concrete and fill all voids so that the water comes to the surface and that the mass quakes under the blows of the rammer and will show a smooth face when the forms are removed. The weight and shape of the rammers used shall be satisfactory to the engineer.

The contractor shall construct suitable forms, the interior shape and dimensions of which shall be such that the finished concrete shall be of the form and dimensions shown on the plans. All forms shall be set true to the lines designated and shall be so built as to remain firm and secure until the concrete is perfectly hardened. All forms shall be satisfactory to the engineer and shall remain in place so long as he deems necessary. Matched and dressed lumber shall be used for those portions of the form which come in contact with concrete surfaces that will be exposed. All forms shall be so constructed that, when removed, all exposed surfaces of the concrete shall be smooth and even.

No piece of stone shall be left within two inches of an exposed surface. A broad-tined fork shall be used to pry the fragments of stone back from the face of the forms.

When the mercury falls below 20° F., newly laid concrete shall be covered with canvas and otherwise protected to prevent freezing.

Concrete work shall not be done during freezing weather. In warm weather concrete shall be covered with canvas, grass, weeds, or otherwise protected from the sun, and shall be wet down until thoroughly set.

surface shall be formed of mortar of the same pro-
d of the same kind and quality of cement and sand
ich forms the matrix of the concrete, and shall be
cutting off the excess with a straight-edge and then
: surface until smooth. As soon as the forms are
ll exposed surfaces shall be rubbed smooth with a
.ter. No plastering of any surface will be allowed, the
ish being obtained by rubbing down the irregularities
All faces shall show a smooth, dense surface, without
rities, blow-holes, or bubbles. All edges, joints of sec-
ther exposed angles of structures shall be beveled or
a regular curve.
:rete which is porous, or which has been plastered,
ıoved and replaced at the expense of the contractor.
shall not be laid in running water, nor shall it be
water nor exposed to the action of water before it
ept with special permission of the engineer, and then
ıner as he may specially direct.
of concrete includes the forms and all labor on same,
ıishing, mixing, and placing of the concrete, but does
any embedded steel or iron.

CRETE FOUNDATION FOR PAVEMENT

foundation for pavement shall be constructed where
. the plans or ordered by the engineer.
ıe constructed in accordance with the specifications
of concrete called for, and shall conform to the details
ıe standard structure sheet.
ıg will be considered a part of the pavement founda-
ıll be constructed in accordance with the specifications
edging.
will include the concrete, placing same, and all labor
ıecessary to put same in place complete.

GRAVEL CONCRETE

ıncrete, when permitted, shall be used in such places
forms and dimensions as may be shown on the plan
ed by the engineer. Before any gravel shall be used
a sample, containing at least 1½ cubic feet, shall be
he contractor, in the presence of the engineer, and
ı the State Commission of Highways, Albany, N.Y.,
When gravel from an accepted source of supply does
e to be satisfactory to the Commission, the contractor
ıired to secure satisfactory gravel elsewhere without
ensation. Gravel concrete must in all respects con-
specifications for stone concrete except as hereinafter

ification, gravel will be separated into three grades
means of two screens having openings 2-in. square

and ¼-in. square respectively. Material passing the ¼-in. screen will be designated as sand, and that passing the 2-in. screen and retained on the ¼-in. screen as screen gravel, and that retained on the 2-in. screen as boulders.

The sand shall meet the specifications for sand in concrete. The screened gravel and boulders shall consist of sound unweathered stone, free from disintegrated matter or shale.

If the portions of gravel, as taken from the bank, contain between 45 and 55 per cent of sand, it may be mixed directly with the cement, in the proportion of one part of cement to six parts of gravel; but if the percentage of sand is greater or less than the above-mentioned limits, it shall be made to meet those requirements by the addition of the necessary amount of either sand or screened gravel, as the case may require, before the addition of the cement to the gravel.

Whenever so directed by the engineer, the contractor shall separate the bank gravel into the two grades mentioned above, in order that the engineer may determine the amount of bank gravel to be mixed with the cement, which will give the above proportions of mixture; and to ascertain if the bank gravel is keeping within the specified limits.

In proportioning sand, cement, and gravel, all material shall be measured in loose bulk in boxes or forms of known capacity satisfactory to the engineer.

Material graded as boulders may be embedded in the concrete in the same manner as specified for stone and stone concrete.

CONCRETE CURBING

Concrete curbing shall be constructed where called for on the plans or ordered by the engineer.

It shall be constructed with or without concrete gutter, according to the details shown on the plans and of the first-class concrete.

All curbing shall be molded in place and cut in sections six feet long.

If called for on the plans or ordered by the engineer, the top face of curbing for a thickness of one inch shall be composed of one part Portland cement and two parts sand as specified, shall be laid before the concrete has attained its initial set, and shall be thoroughly troweled to the section shown on the plans.

Trenches for concrete curb shall be excavated to the width and depth shown on plans, and all material so excavated will be classified as excavation.

Where called for on the plans or ordered by the engineer, porous drain tile shall be placed under concrete curb and firmly bedded in the cinders, gravel, or crushed stone on which the curb is placed.

After the removal of forms the trench shall be filled with earth thoroughly tamped.

The forms shall remain in place on concrete curbing for at

least ten days, and the concrete shall not be walked upon or disturbed in any way during that time, except that if metal forms are used they may be removed after forty-eight hours, and planks substituted to protect it.

The item of concrete curb will include material for foundation, porous drain tile, the concrete, placing same, filling, tamping in place, and all necessary work connected therewith.

CONCRETE EDGING

Concrete edging shall be constructed where called for on the plans or ordered by the engineer. It shall be composed of second-class concrete except that the top face for the thickness of one inch shall be composed of one part Portland cement and two and one-half parts of sand, and shall be laid before the concrete has attained its initial set, and shall be thoroughly troweled to the sections shown on the plan.

Trenches for concrete edges shall be excavated to the depth and width shown on the plans, and all material so excavated shall be classed as excavation.

After the removal of forms the trenches shall be filled with earth and thoroughly tamped.

The forms shall remain in place on concrete edging for at least ten days, and the concrete shall not be walked upon or disturbed in any way during that time.

The item of concrete edging will include the concrete, placing same, filling, and all necessary work connected therewith.

STONE CURBING

Stone curbing shall be set where called for on the plans or ordered by the engineer.

It shall be sound and uniform*------ ------ of an approved quality, free from seams and other imperfections, and shall be not less than five inches thick and eighteen and one-half inches in depth; the lengths may vary between three and six feet.

The upper face shall be cut to the slope shown on plans. The front for a space of ten inches from the top shall be dressed to an even surface, with no projection or depression exceeding one-fourth of an inch. The bottom shall be roughed off parallel to the top, with projections not exceeding two inches beyond the required depth.

The ends for a space ten inches below the top shall be truly squared and dressed for form joints not exceeding one-eighth of an inch thick for a depth of at least two inches from the top, and back two inches from the front face. The joints of circular curbing shall be cut truly radial.

The curbing shall be set to the line and grade given by the engineer.

Trenches for stone curbing shall be excavated to the width

*Note.—Kind of stone as Berea Sandstone, etc.

and depth shown on the plans, and all material so excavated will be classified as excavation.

As called for on the plans, or ordered by the engineer, porous drain tile shall be placed under stone curbing, and firmly bedded in cinders, gravel, or crushed stone, on which the curbing shall be placed and firmly settled to grade by ramming, so that each curbstone shall have an even bearing throughout its entire length.

After curbing has been set as above, trenches shall be filled with earth thoroughly tamped.

The item of stone curbing in place complete will include the curbing, setting same, material for foundation, porous drain-tile laying and tamping in place, and all necessary labor connected therewith.

STONE CURBING — SET IN CONCRETE

Stone curbing set in concrete shall be set where called for on the plans or ordered by the engineer.

It shall be sound and uniform* ——— ——— of an approved quality, free from seams and other imperfections, and shall not be less than five inches thick and twelve inches in depth; the length may vary between three and six feet.

The upper face shall be cut to the slope shown on the plans. The front for a space of ten inches from the top shall be dressed to an even surface, with no projections or depressions exceeding one-quarter of an inch. The bottom shall be roughed off parallel to the top, with projections not exceeding two inches beyond the required depth.

The ends for a space of ten inches below the top shall be truly squared and dressed to form joints not exceeding one-eighth of an inch thick for a depth of at least two inches from the top, and back two inches from the front face. The joints of circular curbing shall be cut truly radial.

The curbing shall be set to the line and grade given by the engineer.

Trenches for "Stone Curbing — set in Concrete" shall be classified as excavation.

The curbing shall be set in third-class concrete as shown on the standard structure sheet.

CONCRETE RETAINING WALLS

Concrete retaining walls of gravity type shall be constructed where called for on the plans or ordered by the engineer.

They shall be constructed so as to conform with the details shown on the plans, and in accordance with the specifications for the class of concrete specified.

***Reinforced* Concrete Retaining Walls.**

Reinforced concrete retaining walls shall be constructed where

* Note.—Kind of stone as Berea Sandstone, etc.

ılled for on the plans or ordered by the engineer. They shall e constructed according to the details of the plans and of first-:ass concrete unless otherwise specified.

All reinforcement shall be of medium steel which shall fulfil ıe prescribed tests.

All reinforced concrete shall be built by workmen and under ›remen who are thoroughly experienced in modern methods of :inforced concrete construction.

Walls shall be divided into sections, and as the engineer may etermine to be necessary or desirable; each section shall form a ıonolith, and work once begun thereon shall be continued without ıterruption until the section is completed.

All forms shall have sufficient strength to hold the work to ıe lines shown on the plans, and shall not be removed within :n days.

No load shall be allowed upon or against any reinforced con-:ete wall within twenty-one days after the completion thereof.

The reinforcement must be fastened securely in place so that will not be displaced in depositing the concrete.

Weep holes shall be constructed where called for on the plans : ordered by the engineer.

Cobblestone, field stone, crusher tailings, No. 3 or No. 4 :avel shall be used for back-filling within the limits shown on ıe plans or ordered by the engineer. The larger stones shall be laced at the bottom and the smallest at the top, care being taken ı arrange the stones around the weep holes that they may ıaintain their maximum efficiency.

No gravel shall be used in reinforced concrete retaining walls.

CONCRETE CULVERTS

Culverts shall be built where called for on the contract plans : required as extra work. The covers, the side walls, and abut-ents shall each be of the class of concrete shown on the plans. ulverts, side walls, or abutments may be of cement masonry ith stone paving when so indicated. In either case they shall : built in accordance with the details shown on the standard ans. Existing culverts shall be lengthened or repaired as ıown on the plans or as directed by the engineer. Mesh rein-ırcement or deformed bars of medium steel shall be used to :inforce concrete as shown on the plans.

BRICK PAVEMENT

The subgrade must be prepared so that after the same has been ılled as specified, it will conform to the cross-section shown on ıe drawings.

When sufficient material has been excavated, the subgrade ıall be rolled with a self-propelled road-roller until thoroughly ımpacted. The surface shall then be trued up to conform with ıe *cross-section by* means of pick and shovel, and rerolled.

When solid rock is encountered in subgrading, same shall be removed to a depth of six inches below the finished surface of the brick, and the bed leveled up with concrete.

Concrete shall be second-class and mixed as specified under concrete.

The top face of edging for a thickness of one inch shall be composed of one part Portland cement and two and one-half parts sand as specified, shall be laid before the concrete has attained its initial set, and shall be thoroughly troweled to the section shown on the drawings.

Upon the foundation, as specified, shall be laid a bed of clean dry sand, which shall be 1½ inches thick when pavement is complete. The sand cushion shall be rolled with a hand roller weighing about 200 pounds and then brought to the exact form and crown by means of a templet of the proper shape, resting on the curbs or on scantling embedded in the sand. The templet shall be drawn forward and backward immediately in front of the bricklaying, so that the sand cushion shall be maintained constantly at the proper crown.

On this sand bed the brick shall be set on edge at right angles at the edging line, except at road intersections, where they shall be laid at such angles and in such manner as the engineer may direct. All longitudinal joints must be broken by a lap of half the length of the brick.

The brick shall be laid in close contact with each other by skilled workmen, who shall stand on the bricks already laid; and in no case shall the bed of sand in front of the pavement be disturbed or walked on after having been smoothed over and brought to the exact crown and grade. All brick to be laid with the lugs in the same direction, so that there will be sufficient space between each row for grouting. After the brick are laid, the end joints are to be made close and compact by the use of a steel bar applied to the ends next to the curbs. At every fourth course, or as often as directed, the side joints are to be closed up as much as possible and the courses straightened in a manner satisfactory to the engineer. Nothing but whole brick shall be used, except in starting for finishing a course.

In all cases the end joints shall be made close and tight. The cutting and trimming of brick shall be done by experienced men, and proper care taken not to check or fracture the part to be used; the joints all to be at right angles to the tops and sides. After a sufficient number of brick have been laid, the pavement shall be thoroughly wet by sprinkling, and all soft, broken, or badly misshaped brick will be marked and removed by the inspector or his assistants. Brick slightly spalled or kiln-marked will be marked to turn over, and should the opposite face be acceptable, it may remain in the pavement, otherwise it shall be removed. The contractor shall immediately remove all rejected brick from the pavement, using tongs with broad flat noses and long stout handles. The spaces so left shall be filled with new

rick, care being taken in making such replacements that the rick so replaced are in conformity with the specifications for aving brick; and all rejected brick shall be at once removed om the highway.

Fourteen days after the placing of the concrete, and after all bjectionable bricks are removed from the pavement and all :placements made, the pavement shall be swept clean and thor- ughly rolled with a light roller, as specified, until the bricks are ıoroughly and evenly bedded in the sand cushion. Any un- venness or irregularities of the surface after rolling shall be ·ued by means of ramming, using a heavy paver's rammer on two-inch plank laid parallel with the edging.

For rolling brick surface, a roller shall be used which will eigh approximately five tons, self-propelled roller preferred.

When a roller of the asphalt, or two-wheel type, is used for olling brick surface a weight of ten tons is allowable; but should ıe grade of the road be such that the roller tips the brick, a ghter roller must be provided.

An expansion cushion must be provided for next to each edging; must be one and one-half inches in thickness for a pavement xteen feet wide and increased proportionately for greater widths.

After rolling, the brick will be again inspected and any neces- ıry replacements made as above specified, such replaced brick be settled into place by ramming.

After the inspection has been completed the joints shall be lled with grout to the full depth of the brick, as specified, in ıe following manner:

Grout for filling the joints of brick or block stone pavements ıall be composed of one part Portland cement as specified and ne part of fine sharp sand as specified; the cement and sand be thoroughly mixed together dry in a box of the proper form nd capacity, and afterwards only a sufficient amount of water dded to make the grout of the proper fluidity when thoroughly .irred. The grout shall be prepared only in small quantities t a time and shall be stirred rapidly and constantly in the box nd while being applied to the pavement.

Grout must be applied immediately on mixing. No residue r settlings shall be used.

The grout shall be mixed to the consistency of thin cream.

The mixture shall be removed from the box to the street surface y means of scoop shovels, and from the moment it touches the rick shall be thoroughly swept into all joints by means of push rooms. The work of grouting shall be thus carried forward the en- re width of the pavement in line until sufficient time has elapsed ır the grout to thoroughly penetrate all joints, but before the ement has attained its initial set. The entire force shall then o over the same portion of the work for a second time, using the ıme mixture of grout, care being taken in each instance to ıoroughly fill all joints flush with the top of the brick. To secure

flush joints, a third, fourth, or fifth coat of cement shall then be swept in and smoothed off with a squeegee.

After the joints are thus filled flush with the top of the bricks and sufficient time for hardening has taken place, so that the coating of sand will not absorb any of the moisture from the cement mixture, one-half inch of sand shall be spread over the whole surface, and an occasional sprinkling, sufficient to dampen the sand, shall be followed for six days.

The grouting thus finished must remain absolutely free from disturbance or traffic of any kind for a period of ten days.

In laying brick pavement the inspector will keep the brick culled and the contractor shall make the necessary changes and replacements, so that the work will at all times be ready for grouting up to within a distance of not more than three hundred feet from the bricklaying.

It is essential that the board occupying the place to be filled with pitch remain in place until after the highway is in all other respects finished, but always withdrawn and the pitch or asphalt applied within thirty-six hours after the application of the cement filler. After the board is withdrawn this joint must be thoroughly cleaned, to the full depth of the brick, before filling.

In the engineer's estimate the approximate quantity of brick pavement does not include the surface area of the edging.

The square yardage of brick pavement for the purpose of ascertaining additions or deductions will be obtained by multiplying the length along the pavement by the width between inside faces of edging.

In hauling brick from the car, no throwing or dumping will be allowed.

The item of brick pavement will include sand cushion, brick, grout, pitch filler for expansion joints, sand covering, sprinkling, and all labor necessary to put the same in place complete.

MEDINA SANDSTONE BLOCK PAVEMENT

(City of Rochester, N.Y., Specifications, 1911)

The grading, subwork, and curbs having been completed as herein specified under the proper headings, the work of laying the concrete foundation and paving will then proceed.

A concrete foundation six (6) inches thick, of Portland cement, as specified in the bidding sheet and shown in plans, will be laid in accordance with the specifications herein contained. The surface will be eight (8) inches below the finished pavement and parallel thereto, or seven (7) inches if a five (5) inch block is specified.

The surface to be kept wet until covered with sand, and, at least, thirty-six (36) hours shall be allowed for the concrete to set before the pavement is laid. When connection is to be made with any layer set, or partially set, the edge of such layer must be broken down, shall be free from dust and properly wet, so as to make the joints fresh and close. On this concrete foundation

ıll be laid a bed of clean, sharp sand, perfectly free from moisture ade so by artificial heat if deemed necessary), not less than one inch thick, to the depth necessary to bring the pavement and sswalks to the proper grade when thoroughly rammed.

Jpon this bed of sand, the stone blocks and crosswalks must be 1. The stone blocks are to be laid in straight courses at ht angles with the line of the street, except in intersections of eets, where the courses shall be laid diagonally, and except special cases, when they shall be laid at such angle, with such wn and at such grade as the city engineer may direct. Each ırse of blocks shall be uniform in width and depth, and shall gauged and selected for the pavers on the sidwalks, and so 1 that *all longitudinal joints or end joints shall be close joints 1 shall be broken by a lap of at least three inches*, and that joints :ween courses shall not be more than one-half inch in width. e blocks shall then be thoroughly rammed by courses at least ee times by a rammer weighing not less than eighty (80) ınds — no iron of any kind being allowed on its lower face to ne in contact with the paving, and until brought to an unlding bearing, with a uniform surface, true to the roadway on : established grade. The surface of the pavement thus comted must be even and smooth throughout and molded to ıform to the wells of the surface sewers, street and alley inter:tions, drainage details, and the grade lines established by the y engineer. During the final ramming the pavement shall be ted with a straight-edge and templet, and any unevenness ıst be taken out and made true to the required grade, level, and ss-section.

If a paving pitch filler is used, the joints shall be filled with an, dry, hot gravel of proper size as herein specified, heated pans especially provided for that purpose, and poured from ıs having small spouts and thoroughly settled in place with re picks until the level of the gravel is at least two inches ow the top of the pavement.

The gravel used between the blocks shall be of such size as l pass through a sieve having four meshes per square inch, and retained on a sieve of sixty-four meshes per square inch, and ıst be screened when dry.

There shall be immediately poured into the joints, while the ıvel is hot, boiling paving cement as hereinafter described, ıted to a temperature of 300° F. until the joints and all inter:es of gravel filling are full and will take no more, and are filled sh with the top of the blocks. Dry, hot gravel must then be ıred along the joints, filled with paving cement, as above scribed.

The paving cement to be used in filling the joints as herein ovided shall be a paving pitch of the best quality, of a brand t has been proved by actual use in pavements known to the y engineer to be best adapted to the purpose. It shall be ivered on the work in lots at least one week before using, in

order that the necessary analysis and examination may be made by the city engineer. In addition to this the contractor must furnish the city engineer with the certificate of the manufacturer or refiner that the materials are of the kind specified.

The city engineer may direct that a Portland cement grout filler may be used in the joints instead of a paving pitch, in which case the pavement shall be thoroughly sprinkled or washed with water before grouting. The grout shall be mixed with clean, sharp sand of approved quality, in the proportion of one to one, the cement and sand to be thoroughly mixed together dry, in a box, and then only a sufficient amount of water added to make the grout of the proper fluidity when thoroughly stirred.

The grout shall be prepared only in small quantities at a time, and shall be stirred rapidly and constantly in the box and while being applied to the pavement, and no settlings or residue will be allowed to be used.

The grout shall be transferred to the pavement in such a way as the engineer may think most advantageous and best for the work, and shall then be rapidly swept into the joints of the pavement with proper brooms. The stones shall be well wet as directed before the grout is applied, and the pouring must be continued until the joints remain full.

All teams and traffic of any kind, except on planks, shall be rigidly prohibited on the pavement for ten days after the grout is applied, or until, in the opinion of the engineer, it has become thoroughly set and hardened, so that the bond will not be broken by traffic over the pavement.

Conversion Table 55

Linear Units

Old Surveyors' Units

1 link	=	7.92 in.		
100 links	=	1 chain	=	66 ft.
25 links	=	1 rod	=	16.5 ft.

Ordinary Measure

12 in.	=	1 ft.
3 ft.	=	1 yd.
5280 ft.	=	1 mile

Square Units

1 sq. ft.	=	144 sq. in.
1 sq. yd.	=	9 sq. ft.
	=	1296 sq. in.
1 acre	=	43,560 sq. ft.
	=	4840 sq. yds.
1 sq. mile	=	27,878,400 sq. ft.
	=	3,097,600 sq. yds.
	=	640 acres

Volume Units

1 cu. ft.	=	1728 cu. in.
	=	7.4805 ordinary gal.
	=	6.232 Imperial gal.
1 cu. yd.	=	27 cu. ft.
	=	46,656 cu. in.
1 ordinary gal.	=	231 cu. in.
1 Imperial gal.	=	277 cu. in.
1 barrel	=	31.5 gal.
	=	4.21 cu. ft.

Weight Units

1 pound	=	16 ounces
1 ordinary ton	=	2000 pounds
1 long ton	=	2240 pounds

Temperature Units

Freezing point of water	=	32° Fahrenheit
	=	0° Centigrade
Boiling point of water at normal air pressure	=	212° Fahrenheit
	=	100° Centigrade
1 degree Fahrenheit	=	0.5556 degree Centigrade
1 degree Centigrade	=	1.8 degrees Fahrenheit

Table 56
Equivalents of Inches and Fractions of Inches in Decimals of a Foot

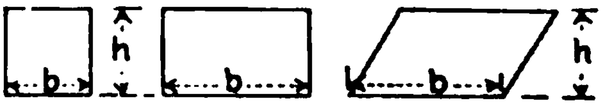
In.	0 In.	1 In.	2 In.	3 In.	4 In.	5 In.
		.0833	.1667	.2500	.3333	.4167
1/32	.0026	.0859	.1693	.2526	.3359	.4193
1/16	.0052	.0885	.1719	.2552	.3385	.4219
3/32	.0078	.0911	.1745	.2578	.3411	.4245
1/8	.0104	.0938	.1771	.2604	.3438	.4271
5/32	.0130	.0964	.1797	.2630	.3464	.4297
3/16	.0156	.0990	.1823	.2656	.3490	.4323
7/32	.0182	.1016	.1849	.2682	.3516	.4349
1/4	.0208	.1042	.1875	.2708	.3542	.4375
9/32	.0234	.1068	.1901	.2734	.3568	.4401
5/16	.0260	.1094	.1927	.2760	.3594	.4427
11/32	.0286	.1120	.1953	.2786	.3620	.4453
3/8	.0313	.1146	.1979	.2813	.3646	.4479
13/32	.0339	.1172	.2005	.2839	.3672	.4505
7/16	.0365	.1198	.2031	.2865	.3698	.4531
15/32	.0391	.1224	.2057	.2891	.3724	.4557
1/2	.0417	.1253	.2083	.2917	.3750	.4583
17/32	.0443	.1276	.2091	.2943	.3776	.4609
9/16	.0469	.1302	.2135	.2969	.3802	.4635
19/32	.0495	.1328	.2161	.2995	.3828	.4661
5/8	.0521	.1354	.2188	.3021	.3854	.4688
21/32	.0547	.1380	.2214	.3047	.3880	.4714
11/16	.0573	.1406	.2240	.3073	.3906	.4740
23/32	.0599	.1432	.2266	.3099	.3932	.4766
3/4	.0625	.1458	.2292	.3125	.3958	.4792
25/32	.0651	.1484	.2318	.3151	.3984	.4818
13/16	.0677	.1510	.2344	.3177	.4010	.4844
27/32	.0703	.1536	.2370	.3203	.4036	.4870
7/8	.0729	.1563	.2396	.3229	.4063	.4896
29/32	.0755	.1589	.2422	.3255	.4089	.4922
15/16	.0781	.1615	.2448	.3281	.4115	.4948
31/32	.0807	.1641	.2474	.3307	.4141	.4974

IVALENTS OF INCHES AND FRACTIONS OF INCHES IN DECIMALS OF A FOOT

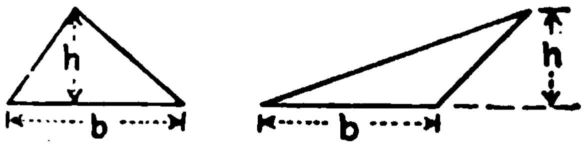
6 In.	7 In.	8 In.	9 In.	10 In.	11 In.
.5000	.5833	.6667	.7500	.8333	.9167
.5026	.5859	.6693	.7526	.8359	.9193
.5052	.5885	.6719	.7552	.8385	.9219
.5078	.5911	.6745	.7578	.8411	.9245
.5104	.5938	.6771	.7604	.8438	.9271
.5130	.5964	.6797	.7630	.8464	.9297
.5156	.5990	.6823	.7656	.8490	.9323
.5182	.6016	.6849	.7682	.8516	.9349
.5208	.6042	.6875	.7708	.8542	.9375
.5234	.6068	.6901	.7734	.8568	.9401
.5260	.6094	.6927	.7760	.8594	.9427
.5286	.6120	.6953	.7786	.8620	.9453
.5313	.6146	.6979	.7813	.8646	.9479
.5339	.6172	.7005	.7839	.8672	.9505
.5365	.6198	.7031	.7865	.8698	.9531
.5391	.6224	.7057	.7891	.8724	.9557
.5417	.6250	.7083	.7917	.8750	.9583
.5443	.6276	.7109	.7943	.8776	.9609
.5469	.6302	.7135	.7969	.8802	.9635
.5495	.6328	.7161	.7995	.8828	.9661
.5521	.6354	.7188	.8021	.8854	.9688
.5547	.6380	.7214	.8047	.8880	.9714
.5573	.6406	.7240	.8073	.8906	.9740
.5599	.6432	.7266	.8099	.8932	.9766
.5625	.6458	.7292	.8125	.8958	.9792
.5651	.6484	.7318	.8151	.8984	.9818
.5677	.6510	.7344	.8177	.9010	.9844
.5703	.6536	.7370	.8203	.9036	.9870
.5729	.6563	.7396	.8229	.9063	.9896
.5755	.6589	.7422	.8255	.9089	.9922
.5781	.6615	.7448	.8281	.9115	.9948
.5807	.6641	.7474	.8307	.9141	.9974

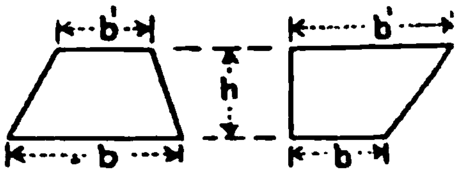
TABLE 57. AREAS AND VOLUMES

Areas

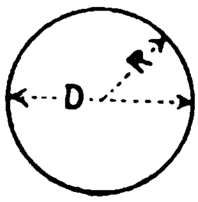


Squares, Rectangles, and Parallelograms. Area $= bh$





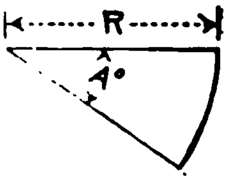
Triangles Area $= \frac{1}{2}\, bh$ *Trapezoids* Area $= \frac{b + b'}{2} h$



Circles

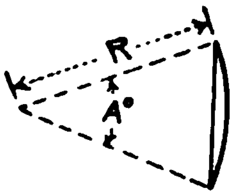
$$\text{Area} = \pi R^2 = \frac{\pi D^2}{4}$$

Circumference of Circle $= 2\pi R = \pi D$
Commonly used value of $\pi = 3.1416$



Sector of Circle

$$\text{Area} = \pi R^2 \frac{A^\circ}{360^\circ}$$



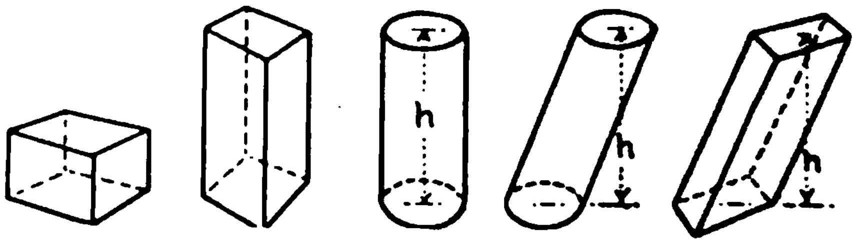
Segment of a Circle

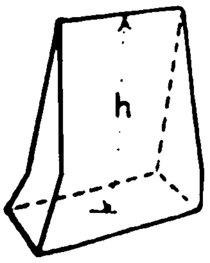
$$\text{Area} = \left(\pi R^2 \frac{A^\circ}{360^\circ}\right) - \left(\left(R \sin \frac{A}{2}\right)\left(R \cos \frac{A}{2}\right)\right)$$

Volumes

Cubes, Rectangular Prisms, Parallelopipeds, Cylinders, etc. All solids having parallel bases and a constant cross-section.

Volume = area of base × perpendicular height between the planes of the bases.



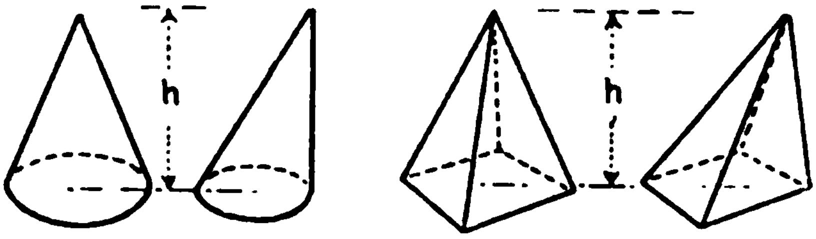


Wedges. Having parallel ends.

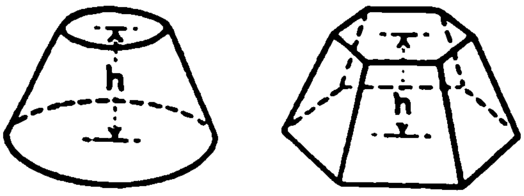
Volume = area of base × ½ the height perpendicular to the plane of the base.

Cones and Pyramids, whether right or oblique, regular or irregular.

Volume = $\frac{1}{3}$ area of the base × height perpendicular to the plane of the base



Frustums of Pyramids or Cones, whether right or oblique, regular or irregular provided the base and top are parallel.



$$\text{Volume} = \tfrac{1}{3} \text{ perpendicular height between base and top} \times \left(\text{area top} + \text{area base} + \sqrt{\text{area top} \times \text{area base}}\right)$$

or by the prismoidal formula

$$\text{Volume} = \tfrac{1}{6} \text{ perpendicular height between base and top} \times \left(\text{area top} + \text{area base} + 4 \times \text{area of section parallel to and midway between base and top}\right)$$

Prismoidal Formula

Trautwine defines a prismoid as a solid having for its ends two parallel plane figures connected by other plane figures on which and through every point of which a straight line may be drawn from one of the two parallel ends to the other. These connecting planes may be parallelograms or not and parallel to each other or not. This includes cubes, all parallelopipeds, prisms, cylinders, pyramids, cones, and their frustums, provided the top and base are parallel and wedges.

The prismoidal formula applies to all these solids either alone or to any form that can be separated into units of the above forms.

Prismoidal formula

$$\text{Volume} = h \times \frac{A + a + 4M}{6}$$

h = perpendicular distance between the parallel ends

A = area of one of the parallel ends

a = area of the other parallel end

M = area of a cross-section midway between and parallel to the two parallel ends

Sphere

$$\text{Volume} = \tfrac{4}{3}\pi R^3 = 4.1888\, R^3$$
$$= \tfrac{1}{6}\pi D^3 = 0.5236\, D^3$$

In which R = radius of sphere

D = diameter of sphere

TABLE 58

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFE
AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	CIRCLE Circum.	
1	1	1	1.0000	1.0000	3.142	
2	4	8	1.4142	1.2599	6.283	
3	9	27	1.7321	1.4422	9.425	
4	16	64	2.0000	1.5874	12.566	1
5	25	125	2.2361	1.7100	15.708	1
6	36	216	2.4495	1.8171	18.850	2
7	49	343	2.6458	1.9129	21.991	3
8	64	512	2.8284	2.0000	25.133	5
9	81	729	3.0000	2.0801	28.274	6
10	100	1000	3.1623	2.1544	31.416	7
11	121	1331	3.3166	2.2240	34.558	9
12	144	1728	3.4641	2.2894	37.699	11
13	169	2197	3.6056	2.3513	40.841	1
14	196	2744	3.7417	2.4101	43.982	1
15	225	3375	3.8730	2.4662	47.124	1
16	256	4096	4.0000	2.5198	50.265	2
17	289	4913	4.1231	2.5713	53.407	2
18	324	5832	4.2426	2.6207	56.549	2
19	361	6859	4.3589	2.6684	59.690	2
20	400	8000	4.4721	2.7144	62.832	3
21	441	9261	4.5826	2.7589	65.973	3
22	484	10648	4.6904	2.8020	69.115	3
23	529	12167	4.7958	2.8439	72.257	4
24	576	13824	4.8990	2.8845	75.398	4
25	625	15625	5.0000	2.9240	78.540	4
26	676	17576	5.0990	2.9625	81.681	5
27	729	19683	5.1962	3.0000	84.823	5
28	784	21952	5.2915	3.0366	87.965	6
29	841	24389	5.3852	3.0723	91.106	6
30	900	27000	5.4772	3.1072	94.248	7
31	961	29791	5.5678	3.1414	90.389	7
32	1024	32768	5.6569	3.1748	100.531	8
33	1089	35937	5.7446	3.2075	103.673	8
34	1156	39304	5.8310	3.2396	106.814	9
35	1225	42875	5.9161	3.2711	109.956	9
36	1296	46656	6.0000	3.3019	113.097	101
37	1369	50653	6.0828	3.3322	116.239	107
38	1444	54872	6.1644	3.3620	119.381	113
39	1521	59319	6.2450	3.3912	122.522	11
40	1600	64000	6.3246	3.4200	125.660	1

ARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

s.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
1	1681	68921	6.4031	3.4482	128.81	1320.25
2	1764	74088	6.4807	3.4760	131.95	1385.44
3	1849	79507	6.5574	3.5034	135.09	1452.20
4	1936	85184	6.6332	3.5303	138.23	1520.53
5	2025	91125	6.7082	3.5569	141.37	1590.43
6	2116	97336	6.7823	3.5830	144.51	1661.90
7	2209	103823	6.8557	3.6088	147.65	1734.94
8	2304	110592	6.9282	3.6342	150.80	1809.56
9	2401	117649	7.0000	3.6593	153.94	1885.74
0	2500	125000	7.0711	3.6840	157.08	1963.50
1	2601	132651	7.1414	3.7084	160.22	2042.82
2	2704	140608	7.2111	3.7325	163.36	2123.72
3	2809	148877	7.2801	3.7563	166.50	2206.18
4	2916	157464	7.3485	3.7798	169.65	2290.22
5	3025	166375	7.4162	3.8030	172.79	2375.83
6	3136	175616	7.4833	3.8259	175.93	2463.01
7	3249	185193	7.5498	3.8485	179.07	2551.76
8	3364	195112	7.6158	3.8709	182.21	2642.08
9	3481	205379	7.6811	3.8930	185.35	2733.97
0	3600	216000	7.7460	3.9149	188.50	2827.43
1	3721	226981	7.8102	3.9365	191.64	2922.47
2	3844	238328	7.8740	3.9579	194.78	3019.07
3	3969	250047	7.9373	3.9791	197.92	3117.25
4	4096	262144	8.0000	4.0000	201.06	3216.99
5	4225	274625	8.0623	4.0207	204.20	3318.31
6	4356	287496	8.1240	4.0412	207.35	3421.19
7	4489	300763	8.1854	4.0615	210.49	3525.65
8	4624	314432	8.2462	4.0817	213.63	3631.68
9	4761	328509	8.3066	4.1016	216.77	3739.28
0	4900	343000	8.3666	4.1213	219.91	3848.45
1	5041	357911	8.4261	4.1408	223.05	3959.19
2	5184	373248	8.4853	4.1602	226.19	4071.50
3	5329	389017	8.5440	4.1793	229.34	4185.39
4	5476	405224	8.6023	4.1983	232.48	4300.84
5	5625	421875	8.6603	4.2172	235.62	4417.86
6	5776	438976	8.7178	4.2358	238.76	4536.46
7	5929	456533	8.7750	4.2543	241.90	4656.63
8	6084	474552	8.8318	4.2727	245.04	4778.36
9	6241	493039	8.8882	4.2908	248.19	4901.67
0	6400	512000	8.9443	4.3089	251.33	5026.55

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
81	6561	531441	9.0000	4.3267	254.47	5153.00
82	6724	551368	9.0554	4.3445	257.61	5281.02
83	6889	571787	9.1104	4.3621	260.75	5410.61
84	7056	592704	9.1652	4.3795	263.89	5541.77
85	7225	614125	9.2195	4.3968	267.04	5674.50
86	7396	636056	9.2736	4.4140	270.18	5808.80
87	7569	658503	9.3274	4.4310	273.32	5944.68
88	7744	681472	9.3808	4.4480	276.46	6082.12
89	7921	704969	9.4340	4.4647	279.60	6221.14
90	8100	729000	9.4868	4.4814	282.74	6361.73
91	8281	753571	9.5394	4.4979	285.88	6503.88
92	8464	778688	9.5917	4.5144	289.03	6647.61
93	8649	804357	9.6437	4.5307	292.17	6792.91
94	8836	830584	9.6954	4.5468	295.31	6939.78
95	9025	857375	9.7468	4.5629	298.45	7088.22
96	9216	884736	9.7980	4.5789	301.59	7238.23
97	9409	912673	9.8489	4.5947	304.73	7389.81
98	9604	941192	9.8995	4.6104	307.88	7542.96
99	9801	970299	9.9499	4.6261	311.02	7697.69
100	10000	1000000	10.0000	4.6416	314.16	7853.98
101	10201	1030301	10.0499	4.6570	317.30	8011.85
102	10404	1061208	10.0995	4.6723	320.44	8171.28
103	10609	1092727	10.1489	4.6875	323.58	8332.29
104	10816	1124864	10.1980	4.7027	326.73	8494.87
105	11025	1157625	10.2470	4.7177	329.87	8659.01
106	11236	1191016	10.2956	4.7326	333.01	8824.73
107	11449	1225043	10.3441	4.7475	336.15	8992.02
108	11664	1259712	10.3923	4.7622	339.29	9160.88
109	11881	1295029	10.4403	4.7769	342.43	9331.32
110	12100	1331000	10.4881	4.7914	345.58	9503.32
111	12321	1367631	10.5357	4.8059	348.72	9676.89
112	12544	1404928	10.5830	4.8203	351.86	9852.03
113	12769	1442897	10.6301	4.8346	355.00	10028.7
114	12996	1481544	10.6771	4.8488	358.14	10207.0
115	13225	1520875	10.7238	4.8629	361.28	10386.9
116	13456	1560896	10.7703	4.8770	364.42	10568.3
117	13689	1601613	10.8167	4.8910	367.57	10751.3
118	13924	1643032	10.8628	4.9049	370.71	10935.9
119	14161	1685159	10.9087	4.9187	373.85	11122.0
120	14400	1728000	10.9545	4.9324	376.99	11309.7

RES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
14641	1771561	11.0000	4.9461	380.13	11499.0
14884	1815848	11.0454	4.9597	383.27	11689.9
15129	1860867	11.0905	4.9732	386.42	11882.3
15376	1906624	11.1355	4.9866	389.56	12076.3
15625	1953125	11.1803	5.0000	392.70	12271.8
15876	2000376	11.2250	5.0133	395.84	12469.0
16129	2048383	11.2694	5.0265	398.98	12667.7
16384	2097152	11.3137	5.0397	402.12	12868.0
16641	2146689	11.3578	5.0528	405.27	13069.8
16900	2197000	11.4018	5.0658	408.41	13273.2
17161	2248091	11.4455	5.0788	411.55	13478.2
17424	2299968	11.4891	5.0916	414.69	13684.8
17689	2352637	11.5326	5.1045	417.83	13892.9
17956	2406104	11.5758	5.1172	420.97	14102.6
18225	2460375	11.6190	5.1299	424.12	14313.9
18496	2515456	11.6619	5.1426	427.26	14526.7
18769	2571353	11.7047	5.1551	430.40	14741.1
19044	2628072	11.7473	5.1676	433.54	14957.1
19321	2685619	11.7898	5.1801	436.68	15174.7
19600	2744000	11.8322	5.1925	439.82	15393.8
19881	2803221	11.8743	5.2048	442.96	15614.5
20164	2863288	11.9164	5.2171	446.11	15836.8
20449	2924207	11.9583	5.2293	449.25	16060.6
20736	2985984	12.0000	5.2415	452.39	16286.0
21025	3048625	12.0416	5.2536	455.53	16513.0
21316	3112136	12.0830	5.2656	458.67	16741.5
21609	3176523	12.1244	5.2776	461.81	16971.7
21904	3241792	12.1655	5.2896	464.96	17203.4
22201	3307949	12.2066	5.3015	468.10	17436.6
22500	3375000	12.2474	5.3133	471.24	17671.5
22801	3442951	12.2882	5.3251	474.38	17907.9
23104	3511808	12.3288	5.3368	477.52	18145.8
23409	3581577	12.3693	5.3485	480.66	18385.4
23716	3652264	12.4097	5.3601	483.81	18626.5
24025	3723875	12.4499	5.3717	486.95	18869.2
24336	3796416	12.4900	5.3832	490.09	19113.4
24649	3869893	12.5300	5.3947	493.23	19359.3
24964	3944312	12.5698	5.4061	496.37	19606.7
25281	4019679	12.6095	5.4175	499.51	19855.7
25600	4096000	12.6491	5.4288	502.65	20106.2

Squares, Cubes, Square Roots, Cube Roots, Circumferences and Circular Areas of Nos. from 1 to 520

No.	Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
161	25921	4173281	12.6886	5.4401	505.80	20358.3
162	26244	4251528	12.7279	5.4514	508.94	20612.0
163	26569	4330747	12.7671	5.4626	512.08	20867.2
164	26896	4410944	12.8062	5.4737	515.22	21124.1
165	27225	4492125	12.8452	5.4848	518.36	21382.5
166	27556	4574296	12.8841	5.4959	521.50	21642.4
167	27889	4657463	12.9228	5.5069	524.65	21904.0
168	28224	4741632	12.9615	5.5178	527.79	22167.1
169	28561	4826809	13.0000	5.5288	530.93	22431.8
170	28900	4913000	13.0384	5.5397	534.07	22698.0
171	29241	5000211	13.0767	5.5505	537.21	22965.8
172	29584	5088448	13.1149	5.5613	540.35	23235.2
173	29929	5177717	13.1529	5.5721	543.50	23506.2
174	30276	5268024	13.1909	5.5828	546.64	23778.7
175	30625	5359375	13.2288	5.5934	549.78	24052.8
176	30976	5451776	13.2665	5.6041	552.92	24328.5
177	31329	5545233	13.3041	5.6147	556.06	24605.7
178	31684	5639752	13.3417	5.6252	559.20	24884.6
179	32041	5735339	13.3791	5.6357	562.35	25164.9
180	32400	5832000	13.4164	5.6462	565.49	25446.9
181	32761	5929741	13.4536	5.6567	568.63	25730.4
182	33124	6028568	13.4907	5.6671	571.77	26015.5
183	33489	6128487	13.5277	5.6774	574.91	26302.2
184	33856	6229504	13.5647	5.6877	578.05	26590.4
185	34225	6331625	13.6015	5.6980	581.19	26880.3
186	34596	6434856	13.6382	5.7083	584.34	27171.6
187	34969	6539203	13.6748	5.7185	587.48	27464.6
188	35344	6644672	13.7113	5.7287	590.62	27759.1
189	35721	6751269	13.7477	5.7388	593.76	28055.2
190	36100	6859000	15.7840	5.7489	596.90	28352.9
191	36481	6967871	13.8203	5.7590	600.04	28652.1
192	36864	7077888	13.8564	5.7690	603.19	28952.9
193	37249	7189057	13.8924	5.7790	606.33	29255.3
194	37636	7301384	13.9284	5.7890	609.47	29559.2
195	38025	7414875	13.9642	5.7989	612.61	29864.8
196	38416	7529536	14.0000	5.8088	615.75	30171.9
197	38809	7645373	14.0357	5.8186	618.89	30480.5
198	39204	7762392	14.0712	5.8285	622.04	30790.7
199	39601	7880599	14.1067	5.8383	625.18	31102.6
200	40000	8000000	14.1421	5.8480	628.32	31415.9

ARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

o.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
1	40401	8120601	14.1774	5.8578	631.46	31730.9
2	40804	8242408	14.2127	5.8675	634.60	32047.4
3	41209	8365427	14.2478	5.8771	637.74	32365.5
4	41616	8489664	14.2829	5.8868	640.89	32685.1
5	42025	8615125	14.3178	5.8964	644.03	33006.4
6	42436	8741816	14.3527	5.9059	647.17	33329.2
7	42849	8869743	14.3875	5.9155	650.31	33653.5
8	43264	8998912	14.4222	5.9250	653.45	33979.5
9	43681	9129329	14.4568	5.9345	656.59	34307.0
0	44100	9261000	14.4914	5.9439	659.73	34636.1
1	44521	9393931	14.5258	5.9533	662.88	34966.7
2	44944	9528128	14.5602	5.9627	666.02	35298.9
3	45369	9663597	14.5945	5.9721	669.16	35632.7
4	45796	9800344	14.6287	5.9814	672.30	35968.1
5	46225	9938375	14.6629	5.9907	675.44	36305.0
6	46656	10077696	14.6969	6.0000	678.58	36643.5
7	47089	10218313	14.7309	6.0092	681.73	36983.6
8	47524	10360232	14.7648	6.0185	684.87	37325.3
9	47961	10503459	14.7986	6.0277	688.01	37668.5
0	48400	10648000	14.8324	6.0368	691.15	38013.3
1	48841	10793861	14.8661	6.0459	694.29	38359.6
2	49284	10941048	14.8997	6.0550	697.43	38707.6
3	49729	11089567	14.9332	6.0641	700.58	39057.1
4	50176	11239424	14.9666	6.0732	703.72	39408.1
5	50625	11390625	15.0000	6.0822	706.86	39760.8
6	51076	11543176	15.0333	6.0912	710.00	40115.0
7	51529	11697083	15.0665	6.1002	713.14	40470.8
8	51984	11852352	15.0997	6.1091	716.28	40828.1
9	52441	12008989	15.1327	6.1180	719.42	41187.1
0	52900	12167000	15.1658	6.1269	722.57	41547.6
1	53361	12326391	15.1987	6.1358	725.71	41909.6
2	53824	12487168	15.2315	6.1446	728.85	42273.3
3	54289	12649337	15.2643	6.1534	731.99	42638.5
4	54756	12812904	15.2971	6.1622	735.13	43005.3
5	55225	12977875	15.3297	6.1710	738.27	43373.6
6	55696	13144256	15.3623	6.1797	741.42	43743.5
7	56169	13312053	15.3948	6.1885	744.56	44115.0
8	56644	13481272	15.4272	6.1972	747.70	44488.1
9	57121	13651919	15.4596	6.2058	750.84	44862.7
0	57600	13824000	15.4919	6.2145	753.98	45238.9

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFER AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	A
241	58081	13997521	15.5242	6.2231	757.12	45
242	58564	14172488	15.5563	6.2317	760.27	45
243	59049	14348907	15.5885	6.2403	763.41	46
244	59536	14526784	15.6205	6.2488	766.55	46
245	60025	14706125	15.6525	6.2573	769.69	47
246	60516	14886936	15.6844	6.2658	772.83	47
247	61009	15069223	15.7162	6.2743	775.97	47
248	61504	15252992	15.7480	6.2828	779.12	48
249	62001	15438249	15.7797	6.2912	782.26	48
250	62500	15625000	15,8114	6.2996	785.40	49
251	63001	15813251	15.8430	6.3080	788.54	49
252	63504	16003008	15.8745	6.3164	791.68	49
253	64009	16194277	15.9060	6.3247	794.82	50
254	64516	16387064	15.9374	6.3330	797.96	50
255	65025	16581375	15.9687	6.3413	801.11	51
256	65536	16777216	16.0000	6.3496	804.25	51
257	66049	16974593	16.0312	6.3579	807.39	51
258	66564	17173512	16.0624	6.3661	810.53	52
259	67081	17373979	16.0935	6.3743	813.67	52
260	67600	17576000	16.1245	6.3825	816.81	53
261	68121	17779581	16.1555	6.3907	819.96	53
262	68644	17984728	16.1864	6.3988	823.10	53
263	69169	18191447	16.2173	6.4070	826.24	54
264	69696	18399744	16.2481	6.4151	829.38	54
265	70225	18609625	16.2788	6.4232	832.52	55
266	70756	18821096	16.3095	6.4312	835.66	55
267	71289	19034163	16.3401	6.4393	838.81	55
268	71824	19248832	16.3707	6.4473	841.95	56
269	72361	19465109	16.4012	6.4553	845.09	56
270	72900	19683000	16.4317	6.4633	848.23	57
271	73441	19902511	16.4621	6.4713	851.37	57
272	73984	20123648	16.4924	6.4792	854.51	58
273	74529	20346417	16.5227	6.4872	857.66	58
274	75076	20570824	16.5529	6.4951	860.80	58
275	75625	20796875	16.5831	6.5030	863.94	59
276	76176	21024576	16.6132	6.5108	867.08	59
277	76729	21253933	16.6433	6.5187	870.22	60
278	77284	21484952	16.6733	6.5265	873.36	60
279	77841	21717639	16.7033	6.5343	876.50	61
280	78400	21952000	16.7332	6.5421	879.65	61

RES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

Square	Cube	Sq. Root	Cube Root	Circle Circum.	Circle Area
78961	22188041	16.7631	6.5499	882.79	62015.8
79524	22425768	16.7929	6.5577	885.93	62458.0
80089	22665187	16.8226	6.5654	889.07	62901.8
80656	22906304	16.8523	6.5731	892.21	63347.1
81225	23149125	16.8819	6.5808	895.35	63794.0
81796	23393656	16.9115	6.5885	898.50	64242.4
82369	23639903	16.9411	6.5962	901.64	64692.5
82944	23887872	16.9706	6.6039	904.78	65144.1
83521	24137569	17.0000	6.6115	907.92	65597.2
84100	24389000	17.0294	6.6191	911.06	66052.0
84681	24642171	17.0587	6.6267	914.20	66508.3
85264	24897088	17.0880	6.6343	917.35	66966.2
85849	25153757	17.1172	6.6419	920.49	67425.6
86436	25412184	17.1464	6.6494	923.63	67886.7
87025	25672375	17.1756	6.6569	926.77	68349.3
87616	25934336	17.2047	6.6644	929.91	68813.5
88209	26198073	17.2337	6.6719	933.05	69279.2
88804	26463592	17.2627	6.6794	936.19	69746.5
89401	26730899	17.2916	6.6869	939.34	70215.4
90000	27000000	17.3205	6.6943	942.48	70685.8
90601	27270901	17.3494	6.7018	945.62	71157.9
91204	27543608	17.3781	6.7092	948.76	71631.5
91809	27818127	17.4069	6.7166	951.90	72106.6
92416	28094464	17.4356	6.7240	955.04	72583.4
93025	28372625	17.4642	6.7313	958.19	73061.7
93636	28652616	17.4929	6.7387	961.33	73541.5
94249	28934443	17.5214	6.7460	964.47	74023.0
94864	29218112	17.5499	6.7533	967.61	74506.0
95481	29503629	17.5784	6.7606	970.75	74990.6
96100	29791000	17.6068	6.7679	973.89	75476.8
96721	30080231	17.6352	6.7752	977.04	75964.5
97344	30371328	17.6635	6.7824	980.18	76453.8
97969	30664297	17.6918	6.7897	983.32	76944.7
98596	30959144	17.7200	6.7969	986.46	77437.1
99225	31255875	17.7482	6.8041	989.60	77931.1
99856	31554496	17.7764	6.8113	992.74	78426.7
100489	31855013	17.8045	6.8185	995.88	78923.9
101124	32157432	17.8326	6.8256	999.03	79422.6
101761	32461759	17.8606	6.8328	1002.20	79922.9
102400	32768000	17.8885	6.8399	1005.30	80424.8

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
321	103041	33076161	17.9165	6.8470	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	1049.3	87615.9
335	112225	37595375	18.3030	6.9451	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	1055.6	88668.3
337	113569	38272753	18.3576	6.9589	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	1068.1	90792.0
341	116281	39651821	18.4662	6.9864	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	1096.4	95662.3
350	122500	42875000	18.7083	7.0473	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	1121.5	100098
358	128164	45882712	18.9209	7.1006	1124.7	100660
359	128881	46268279	18.9473	7.1072	1127.8	101223
360	129600	46656000	18.9737	7.1138	1131.0	101788

res, Cubes, Square Roots, Cube Roots, Circumferences and Circular Areas of Nos. from 1 to 520

Square	Cube	Sq. Root	Cube Root	Circle	
				Circum.	Area
130321	47045881	19.0000	7.1204	1134.1	102354
131044	47437928	19.0263	7.1269	1137.3	102922
131769	47832147	19.0526	7.1335	1140.4	103491
132496	48228544	19.0788	7.1400	1143.5	104062
133225	48627125	19.1050	7.1466	1146.7	104635
133956	49027896	19.1311	7.1531	1149.8	105209
134689	49430863	19.1572	7.1596	1153.0	105785
135424	49836032	19.1833	7.1661	1156.1	106362
136161	50243409	19.2094	7.1726	1159.2	106941
136900	50653000	19.2354	7.1791	1162.4	107521
137641	51064811	19.2614	7.1855	1165.5	108103
138384	51478848	19.2873	7.1920	1168.7	108687
139129	51895117	19.3132	7.1984	1171.8	109272
139876	52313624	19.3391	7.2048	1175.0	109858
140625	52734375	19.3649	7.2112	1178.1	110447
141376	53157376	19.3907	7.2177	1181.2	111036
142129	53582633	19.4165	7.2240	1184.4	111628
142884	54010152	19.4422	7.2304	1187.5	112221
143641	54439939	19.4679	7.2368	1190.7	112815
144400	54872000	19.4936	7.2432	1193.8	113411
145161	55306341	19.5192	7.2495	1196.9	114009
145924	55742968	19.5448	7.2558	1200.1	114608
146689	56181887	19.5704	7.2622	1203.2	115209
147456	56623104	19.5959	7.2685	1206.4	115812
148225	57066625	19.6214	7.2748	1209.5	116416
148996	57512456	19.6469	7.2811	1212.7	117021
149769	57960603	19.6723	7.2874	1215.8	117628
150544	58411072	19.6977	7.2936	1218.9	118237
151321	58863869	19.7231	7.2999	1222.1	118847
152100	59319000	19.7484	7.3061	1225.2	119459
152881	59776471	19.7737	7.3124	1228.4	120072
153664	60236288	19.7990	7.3186	1231.5	120687
154449	60698457	19.8242	7.3248	1234.6	121304
155236	61162984	19.8494	7.3310	1237.8	121922
156025	61629875	19.8746	7.3372	1240.9	122542
156816	62099136	19.8997	7.3434	1244.1	123163
157609	62570773	19.9249	7.3496	1247.2	123786
158404	63044792	19.9499	7.3558	1250.4	124410
159201	63521199	19.9750	7.3619	1253.5	125036
160000	64000000	20.0000	7.3684	1256.6	125664

Squares, Cubes, Square Roots, Cube Roots, Circumference, and Circular Areas of Nos. from 1 to 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
401	160801	64481201	20.0250	7.3742	1259.8	126293
402	161604	64964808	20.0499	7.3803	1262.9	126923
403	162409	65450827	20.0749	7.3864	1266.1	127556
404	163216	65939264	20.0998	7.3925	1269.2	128190
405	164025	66430125	20.1246	7.3986	1272.3	128825
406	164836	66923416	20.1494	7.4047	1275.5	129462
407	165649	67419143	20.1742	7.4108	1278.6	130100
408	166464	67917312	20.1990	7.4169	1281.8	130741
409	167281	68417929	20.2237	7.4229	1284.9	131382
410	168100	68921000	20.2485	7.4290	1288.1	132025
411	168921	69426531	20.2731	7.4350	1291.2	132670
412	169744	69934528	20.2978	7.4410	1294.3	133317
413	170569	70444997	20.3224	7.4470	1297.5	133965
414	171396	70957944	20.3470	7.4530	1300.6	134614
415	172225	71473375	20.3715	7.4590	1303.8	135265
416	173056	71991296	20.3961	7.4650	1306.9	135918
417	173889	72511713	20.4206	7.4710	1310.0	136572
418	174724	73034632	20.4450	7.4770	1313.2	137228
419	175561	73560059	20.4695	7.4829	1316.3	137885
420	176400	74088000	20.4939	7.4889	1319.5	138544
421	177241	74618461	20.5183	7.4948	1322.6	139205
422	178084	75151448	20.5426	7.5007	1325.8	139867
423	178929	75686967	20.5670	7.5067	1328.9	140531
424	179776	76225024	20.5913	7.5126	1332.0	141196
425	180625	76765625	20.6155	7.5185	1335.2	141863
426	181476	77308776	20.6398	7.5244	1338.3	142531
427	182329	77854483	20.6640	7.5302	1341.5	143201
428	183184	78402752	20.6882	7.5361	1344.6	143872
429	184041	78953589	20.7123	7.5420	1347.7	144545
430	184900	79507000	20.7364	7.5478	1350.9	145220
431	185761	80062991	20.7605	7.5537	1354.0	145896
432	186624	80621568	20.7846	7.5595	1357.2	146574
433	187489	81182737	20.8087	7.5654	1360.3	147254
434	188356	81746504	20.8327	7.5712	1363.5	147934
435	189225	82312875	20.8567	7.5770	1366.6	148617
436	190096	82881856	20.8806	7.5828	1369.7	149301
437	190969	83453453	20.9045	7.5886	1372.9	149987
438	191844	84027672	20.9284	7.5944	1376.0	150674
439	192721	84604519	20.9523	7.6001	1379.2	151363
440	193600	85184000	20.9762	7.6059	1382.3	152053

ARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

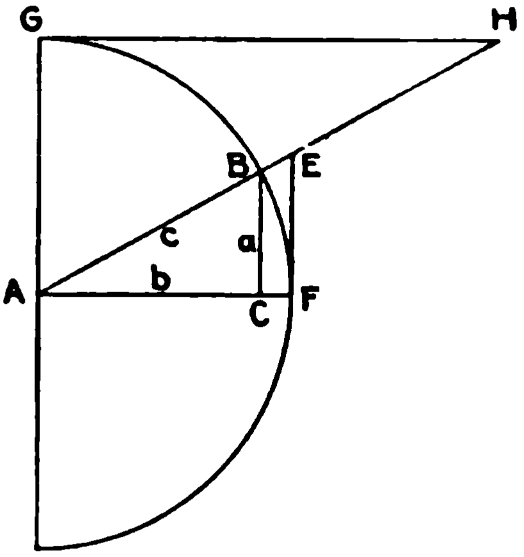
.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
1	194481	85766121	21.0000	7.6117	1385.4	152745
2	195364	86350888	21.0238	7.6174	1388.6	153439
3	196249	86938307	21.0476	7.6232	1391.7	154134
4	197136	87528384	21.0713	7.6289	1394.9	154830
5	198025	88121125	21.0950	7.6346	1398.0	155528
6	198916	88716536	21.1187	7.6403	1401.2	156228
7	199809	89314623	21.1424	7.6460	1404.3	156930
8	200704	89915392	21.1660	7.6517	1407.4	157633
9	201601	90518849	21.1896	7.6574	1410.6	158337
0	202500	91125000	21.2132	7.6631	1413.7	159043
1	203401	91733851	21.2368	7.6688	1416.9	159751
2	204304	92345408	21.2603	7.6744	1420.0	160460
3	205209	92959677	21.2838	7.6801	1423.1	161171
4	206116	93576664	21.3073	7.6857	1426.3	161883
5	207025	94196375	21.3307	7.6914	1429.4	162597
6	207936	94818816	21.3542	7.6970	1432.6	163313
7	208849	95443993	21.3776	7.7026	1435.7	164030
8	209764	96071912	21.4009	7.7082	1438.9	164748
9	210681	96702579	21.4243	7.7138	1442.0	165468
0	211600	97336000	21.4476	7.7194	1445.1	166190
1	212521	97972181	21.4709	7.7250	1448.3	166914
2	213444	98611128	21.4942	7.7306	1451.4	167639
3	214369	99252847	21.5174	7.7362	1454.6	168365
4	215296	99897344	21.5407	7.7418	1457.7	169093
5	216225	100544625	21.5639	7.7473	1460.8	169823
6	217156	101194696	21.5870	7.7529	1464.0	170554
7	218089	101847563	21.6102	7.7584	1467.1	171287
8	219024	102503232	21.6333	7.7639	1470.3	172021
9	219961	103161709	21.6564	7.7695	1473.4	172757
0	220900	103823000	21.6795	7.7750	1476.5	173494
1	221841	104487111	21.7025	7.7805	1479.7	174234
2	222784	105154048	21.7256	7.7860	1482.8	174974
3	223729	105823817	21.7486	7.7915	1486.0	175716
4	224676	106496424	21.7715	7.7970	1489.1	176460
5	225625	107171875	21.7945	7.8025	1492.3	177205
6	226576	107850176	21.8174	7.8079	1495.4	177952
7	227529	108531333	21.8403	7.8134	1498.5	178701
8	228484	109215352	21.8632	7.8188	1501.7	179451
9	229441	109902239	21.8861	7.8243	1504.8	180203
0	230400	110592000	21.9089	7.8297	1508.0	180956

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, CIRCUMFERENCES AND CIRCULAR AREAS OF NOS. FROM 1 TO 520

No.	Square	Cube	Sq. Root	Cube Root	Circle	
					Circum.	Area
481	231361	111284641	21.9317	7.8352	1511.1	181711
482	232324	111980168	21.9545	7.8406	1514.3	182467
483	233289	112678587	21.9773	7.8460	1517.4	183225
484	234256	113379904	22.0000	7.8514	1520.5	183984
485	235225	114084125	22.0227	7.8568	1523.7	184745
486	236196	114791256	22.0454	7.8622	1526.8	185508
487	237169	115501303	22.0681	7.8676	1530.0	186272
488	238144	116214272	22.0907	7.8730	1533.1	187038
489	239121	116930169	22.1133	7.8784	1536.2	187805
490	240100	117649000	22.1359	7.8837	1539.4	188574
491	241081	118370771	22.1585	7.8891	1542.5	189345
492	242064	119095488	22.1811	7.8944	1545.7	190117
493	243049	119823157	22.2036	7.8998	1548.8	190890
494	244036	120553784	22.2261	7.9051	1551.9	191665
495	245025	121287375	22.2486	7.9105	1555.1	192442
496	246016	122023936	22.2711	7.9158	1558.2	193221
497	247009	122763473	22.2935	7.9211	1561.4	194000
498	248004	123505992	22.3159	7.9264	1564.5	194782
499	249001	124251499	22.3383	7.9317	1567.7	195565
500	250000	125000000	22.3607	7.9370	1570.8	196350
501	251001	125751501	22.3830	7.9423	1573.9	197136
502	252004	126506008	22.4054	7.9476	1577.1	197923
503	253009	127263527	22.4277	7.9528	1580.2	198713
504	254016	128024064	22.4499	7.9581	1583.4	199504
505	255025	128787625	22.4722	7.9634	1586.5	200296
506	256036	129554216	22.4944	7.9686	1589.7	201090
507	257049	130323843	22.5167	7.9739	1592.8	201886
508	258064	131096512	22.5389	7.9791	1595.9	202683
509	259081	131872229	22.5610	7.9843	1599.1	203482
510	260100	132651000	22.5832	7.9896	1602.2	204282
511	261121	133432831	22.6053	7.9948	1605.4	205084
512	262144	134217728	22.6274	8.0000	1608.5	205887
513	263169	135005697	22.6495	8.0052	1611.6	206692
514	264196	135796744	22.6716	8.0104	1614.8	207499
515	265225	136590875	22.6936	8.0156	1617.9	208307
516	266256	137388096	22.7156	8.0208	1621.1	209117
517	267289	138188413	22.7376	8.0260	1624.2	209928
518	268324	138991832	22.7596	8.0311	1627.3	210741
519	269361	139798359	22.7816	8.0363	1630.5	211556
520	270400	140608000	22.8035	8.0415	1633.6	212372

Table 59. Trigonometric Functions and the Solution of Triangles

In the accompanying figure the trigonometric functions of the angle A between the lines $B\,A$ and $A\,C$ are as follows;



$$\sin A = B\,C$$
$$\cos A = A\,C$$
$$\tan A = E\,F$$
$$\cot A = G\,H$$
$$\sec A = A\,E$$
$$\operatorname{cosec} A = A\,H$$
$$\text{ex-sec } A = B\,E$$

In the right-angled triangle $A\,B\,C$ let a equal the side $B\,C$ opposite the angle A; let b equal the side $A\,C$ opposite the angle B; let c equal $A\,B$, the side opposite the angle C.

Let $C = 90°$
The following formulæ apply to right-angled triangles:

Angles. $A + B + C = 180°$
$A + B = 90°$
$A = 90° - B$
$B = 90° - A$

Sides. $a = c \sin A = b \tan A$
$a = \sqrt{(c+b)\,(c-b)}$
$b = c \cos. A = \dfrac{a}{\tan A}$
$b = \sqrt{(c+a)\,(c-a)}$
$c = \dfrac{a}{\sin A} = \dfrac{b}{\cos A}$
$c = \sqrt{a^2 + b^2}$

$\sin A = \dfrac{a}{c}$

$\cos A = \dfrac{b}{c}$

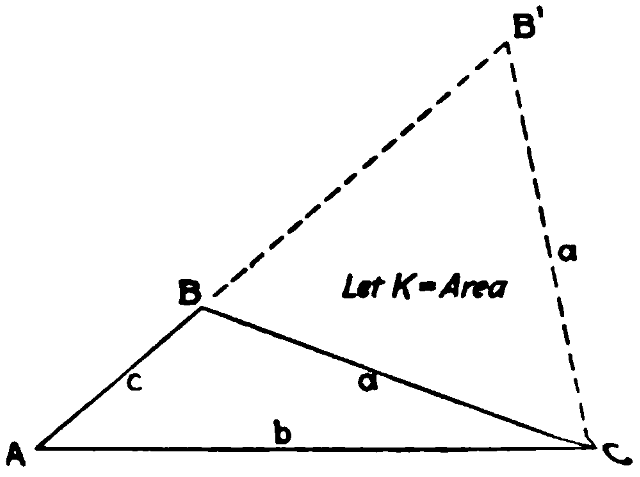
$\tan A = \dfrac{a}{b}$

Area

$$\text{area} = \frac{a\,b}{2}$$

Oblique Triangles.

Note. Where an angle is more than 90° its sine, cosine, and tangent are equal to that of the angle (180° − the angle in question); that is, if the sine of 120° is desired take the sine of (180° − 120°) = 60°.



Given	Desired	Formulæ
A, B, a	C, b	$C = 180 - (A + B)$; $b = \dfrac{a}{\sin A} \sin B$
	c, K	$c = \dfrac{a}{\sin A} \sin (A + B)$; $K = \dfrac{a^2 \sin B \sin C}{2 \sin A}$
A, a, b	B, C	$\sin B = \dfrac{\sin A}{a} b$; $C = 180° - (A + B)$
	c	$c = \dfrac{a}{\sin A} \sin C$ Two solutions are possible with B′ as an acute angle and B as an obtuse angle
C, a, b	$\frac{1}{2}(A+B)$	$\frac{1}{2}(A+B) = 90° - \frac{1}{2} C$
	$\frac{1}{2}(A-B)$	$\tan \frac{1}{2}(A-B) = \dfrac{a-b}{a+b} \tan \frac{1}{2}(A+B)$
	$A\ B$	$A = \frac{1}{2}(A+B) + \frac{1}{2}(A-B)$ $B = \frac{1}{2}(A+B) - \frac{1}{2}(A-B)$
	c	$c = (a - b) \dfrac{\sin \frac{1}{2}(A+B)}{\sin \frac{1}{2}(A-B)}$
	K	$K = \frac{1}{2} ab \sin C$
a, b, c	B	In the following formula $s = \frac{1}{2}(a + b + c)$ $\sin \frac{1}{2} B = \sqrt{\dfrac{(s-a)(s-c)}{ac}}$ $\sin B = \dfrac{2\sqrt{s(s-a)(s-b)(s-c)}}{ac}$
	K	$K = \sqrt{s(s-a)(s-b)(s-c)}$

TABLE 60

′	0°		1°		2°		3°		′
	Tan.	Co-tan.	Tan.	Co-tan	Tan.	Co-tan	Tan.	Co-tan	
0	.00000	Infinite	.01746	57.2900	.03492	28.6363	.05241	19.0811	60
1	.00029	3437.750	.01775	56.3506	.03521	28.3994	.05270	18.9755	59
2	.00058	1718.870	.01804	55.4415	.03550	28.1664	.05299	18.8711	58
3	.00087	1145.920	.01833	54.5613	.03579	27.9372	.05328	18.7678	57
4	.00116	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	56
5	.00145	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	55
6	.00175	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	54
7	.00204	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	53
8	.00233	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	52
9	.00262	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	51
10	.00291	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	50
11	.00320	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	49
12	.00349	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	48
13	.00378	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	47
14	.00407	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	46
15	.00436	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	45
16	.00465	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	44
17	.00495	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	43
18	.00524	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	42
19	.00553	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	41
20	.00582	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	40
21	.00611	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	39
22	.00640	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	38
23	.00669	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	37
24	.00698	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	36
25	.00727	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	35
26	.00756	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	34
27	.00785	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	33
28	.00814	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	32
29	.00844	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	31
30	.00873	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	30
31	.00902	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	29
32	.00931	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	28
33	.00960	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	27
34	.00989	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	26
35	.01018	98.2179	.02764	36.1776	.04512	22.1640	.06262	[illegible]	22
36	.01047	95.4895	.02793	35.8006	.04541	22.0217	.20618	4.85013	21
37	.01076	92.9085	.02822	35.4313	.04570	5.30928	.20648	4.84300	20
38	.01105	90.4633	.02851	35.0695	.18865	5.30080	.20679	4.83590	19
39	.01135	88.1436	.02881	34.7151	.18895	5.29235	.20709	4.82882	18
40	.01164	85.9398	.02910	34.3678	.18925	5.28393	.20739	4.82175	17
41	.01193	83.8435	.02939	5.82982	.18955	5.27553	.20770	4.81471	16
42	.01222	81.8470	.02968	5.81966	.18986	5.26715	.20800	4.80769	15
43	.01251	79.9434	.02997	5.80953	.19016	5.25880	.20830	4.80068	14
44	.01280	78.1263	.17243	5.79944	.19046	5.25048	.20861	4.79370	13
45	.01309	76.3900	.17273	5.78938	.19076	5.24218	.20891	4.78673	12
46	.01338	74.7292	.17303	5.77936	.19106	5.23391	.20921	4.77978	11
47	.01367	73.1390	.17333	5.76937	.19136	5.22566	.20952	4.77286	10
48	.01396	71.6151	.17363	5.75941	.19166	5.21744	.20982	4.76595	9
49	.01425	70.1533	.17393	5.74949	.19197	5.20925	.21013	4.75906	8
50	.01455	68.7501	.17423	5.73960	.19227	5.20107	.21043	4.75219	7
51	.01484	67.4019	.17453	5.72974	.19257	5.19293	.21073	4.74534	6
52	.01513	66.1055	.17483	5.71992	.19287	5.18480	.21104	4.73851	5
53	.01542	64.8580	.17513	5.71013	.19317	5.17671	.21134	4.73170	4
54	.01571	63.6567	.17543	5.70037	.19347	5.16863	.21164	4.72490	3
55	.01600	62.4992	.17573	5.69064	.19378	5.16058	.21195	4.71813	2
56	.01629	61.3829	.17603	5.68094	.19408	5.15256	.21225	4.71137	1
57	.01658	60.3058	.17633	5.67128	.19438	5.14455	.21256	4.70463	0
58	.01687	59.2659							
59	.01716	58.2612	Co-tan	Tan.	Co-tan	Tan.	Co-tan	Tan	
60	.01746	57.2900	80°		79°		78°		
′	Co-tan.	Tan.							
	89°								

Given	Desired	Formulæ
A, B, a	C, b	$C = 180 - (A + B);\ b = \frac{a}{\sin A} \sin$
	c, K	$c = \frac{a}{\sin A} \sin (A + B);\ K = \frac{a^2 \sin B\ \text{si}}{2 \sin}$
A, a, b	B, C	$\sin B = \frac{\sin A}{a} b;\ \ C = 180° - (A +$
	c	$c = \frac{a}{\sin A} \sin C$
		Two solutions are possible with B′ as an acute a **and B as an obtuse angle**
C, a, b	$\frac{1}{2}(A+B)$	$\frac{1}{2}(A+B) = 90° - \frac{1}{2} C$
	$\frac{1}{2}(A-B)$	$\tan \frac{1}{2}(A-B) = \frac{a-b}{a+b}\quad \tan \frac{1}{2}(A +$
	$A\ B$	$A = \frac{1}{2}(A + B) + \frac{1}{2}(A - B)$
		$B = \frac{1}{2}(A + B) - \frac{1}{2}(A - B)$
	c	$c = (a - b) \frac{\sin \frac{1}{2}(A + B)}{\sin \frac{1}{2}(A - B)}$
	K	$K = \frac{1}{2} ab \sin C$
a, b, c	B	In the following formula $s = \frac{1}{2}(a + b$
		$\sin \frac{1}{2} B = \sqrt{\frac{(s - a)(s - c)}{ac}}$
		$\sin B = \frac{2\sqrt{s(s - a)(s - b)(s -}}{ac}$
	K	$K = \sqrt{s(s - a)(s - b)(s - c)}$

TABLE 60

0°		1°		2°		3°		
t.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	′
00	Infinite	.01746	57.2900	.03492	28.6363	.05241	19.0811	60
29	3437.750	.01775	56.3506	.03521	28.3994	.05270	18.9755	59
58	1718.870	.01804	55.4415	.03550	28.1664	.05299	18.8711	58
87	1145.920	.01833	54.5613	.03579	27.9372	.05328	18.7678	57
16	859.436	.01862	53.7086	.03609	27.7117	.05357	18.6656	56
45	687.549	.01891	52.8821	.03638	27.4899	.05387	18.5645	55
75	572.957	.01920	52.0807	.03667	27.2715	.05416	18.4645	54
04	491.106	.01949	51.3032	.03696	27.0566	.05445	18.3655	53
33	429.718	.01978	50.5485	.03725	26.8450	.05474	18.2677	52
62	381.971	.02007	49.8157	.03754	26.6367	.05503	18.1708	51
91	343.774	.02036	49.1039	.03783	26.4316	.05533	18.0750	50
20	312.521	.02066	48.4121	.03812	26.2296	.05562	17.9802	49
49	286.478	.02095	47.7395	.03842	26.0307	.05591	17.8863	48
78	264.441	.02124	47.0853	.03871	25.8348	.05620	17.7934	47
07	245.552	.02153	46.4489	.03900	25.6418	.05649	17.7015	46
36	229.182	.02182	45.8294	.03929	25.4517	.05678	17.6106	45
65	214.858	.02211	45.2261	.03958	25.2644	.05708	17.5205	44
95	202.219	.02240	44.6386	.03987	25.0798	.05737	17.4314	43
24	190.984	.02269	44.0661	.04016	24.8978	.05766	17.3432	42
53	180.932	.02298	43.5081	.04046	24.7185	.05795	17.2558	41
82	171.885	.02328	42.9641	.04075	24.5418	.05824	17.1693	40
11	163.700	.02357	42.4335	.04104	24.3675	.05854	17.0837	39
40	156.259	.02386	41.9158	.04133	24.1957	.05883	16.9990	38
69	149.465	.02415	41.4106	.04162	24.0263	.05912	16.9150	37
98	143.237	.02444	40.9174	.04191	23.8593	.05941	16.8319	36
27	137.507	.02473	40.4358	.04220	23.6945	.05970	16.7496	35
56	132.219	.02502	39.9655	.04250	23.5321	.05999	16.6681	34
85	127.321	.02531	39.5059	.04279	23.3718	.06029	16.5874	33
14	122.774	.02560	39.0568	.04308	23.2137	.06058	16.5075	32
44	118.540	.02589	38.6177	.04337	23.0577	.06087	16.4283	31
73	114.589	.02619	38.1885	.04366	22.9038	.06116	16.3499	30
02	110.892	.02648	37.7686	.04395	22.7519	.06145	16.2722	29
31	107.426	.02677	37.3579	.04424	22.6020	.06175	16.1952	28
60	104.171	.02706	36.9560	.04454	22.4541	.06204	16.1190	27
89	101.107	.02735	36.5627	.04483	22.3081	.06233	16.0435	26
18	98.2179	.02764	36.1776	.04512	22.1640	.06262	15.9687	25
47	95.4895	.02793	35.8006	.04541	22.0217	.06291	15.8945	24
76	92.9085	.02822	35.4313	.04570	21.8813	.06321	15.8211	23
05	90.4633	.02851	35.0695	.04599	21.7426	.06350	15.7483	22
35	88.1436	.02881	34.7151	.04628	21.6056	.06379	15.6762	21
64	85.9398	.02910	34.3678	.04658	21.4704	.06408	15.6048	20
93	83.8435	.02939	34.0273	.04687	21.3369	.06437	15.5340	19
22	81.8470	.02968	33.6935	.04716	21.2049	.06467	15.4638	18
51	79.9434	.02997	33.3662	.04745	21.0747	.06496	15.3943	17
80	78.1263	.03026	33.0452	.04774	20.9460	.06525	15.3254	16
09	76.3900	.03055	32.7303	.04803	20.8188	.06554	15.2571	15
38	74.7292	.03084	32.4213	.04833	20.6932	.06584	15.1893	14
67	73.1390	.03114	32.1181	.04862	20.5691	.06613	15.1222	13
96	71.6151	.03143	31.8205	.04891	20.4465	.06642	15.0557	12
25	70.1533	.03172	31.5284	.04920	20.3253	.06671	14.9898	11
55	68.7501	.03201	31.2416	.04949	20.2056	.06700	14.9244	10
84	67.4019	.03230	30.9599	.04978	20.0872	.06730	14.8596	9
13	66.1055	.03259	30.6833	.05007	19.9702	.06759	14.7954	8
42	64.8580	.03288	30.4116	.05037	19.8546	.06788	14.7317	7
71	63.6567	.03317	30.1446	.05066	19.7403	.06817	14.6685	6
00	62.4992	.03346	29.8823	.05095	19.6273	.06847	14.6059	5
29	61.3829	.03376	29.6245	.05124	19.5156	.06876	14.5438	4
58	60.3058	.03405	29.3711	.05153	19.4051	.06905	14.4823	3
87	59.2659	.03434	29.1220	.05182	19.2959	.06934	14.4212	2
16	58.2612	.03463	28.8771	.05212	19.1879	.06963	14.3607	1
46	57.2900	.03492	28.6363	.05241	19.0811	.06993	14.3007	0
′	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	
89°		88°		87°		86°		

′	12°		13°		14°		15°	
	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-ta
0	.21256	4.70463	.23087	4.33148	.24933	4.01078	.26795	3.7320
1	.21286	4.69791	.23117	4.32573	.24964	4.00582	.26826	3.7277
2	.21316	4.69121	.23148	4.32001	.24995	4.00086	.26857	3.7233
3	.21347	4.68452	.23179	4.31430	.25026	3.99592	.26888	3.7190
4	.21377	4.67786	.23209	4.30860	.25056	3.99099	.26920	3.7147
5	.21408	4.67121	.23240	4.30291	.25087	3.98607	.26951	3.7104
6	.21438	4.66458	.23271	4.29724	.25118	3.98117	.26982	3.7061
7	.21469	4.65797	.23301	4.29159	.25149	3.97627	.27013	3.7018
8	.21499	4.65138	.23332	4.28595	.25180	3.97139	.27044	3.6976
9	.21529	4.64480	.23363	4.28032	.25211	3.96651	.27076	3.6933
10	.21560	4.63825	.23393	4.27471	.25242	3.96165	.27107	3.6890
11	.21590	4.63171	.23424	4.26911	.25273	3.95680	.27138	3.6848
12	.21621	4.62518	.23455	4.26352	.25304	3.95196	.27169	3.6806
13	.21651	4.61868	.23485	4.25795	.25335	3.94713	.27201	3.6763
14	.21682	4.61219	.23516	4.25239	.25366	3.94232	.27232	3.6721
15	.21712	4.60572	.23547	4.24685	.25397	3.93751	.27263	3.6679
16	.21743	4.59927	.23578	4.24132	.25428	3.93271	.27294	3.6637
17	.21773	4.59283	.23608	4.23580	.25459	3.92793	.27326	3.6595
18	.21804	4.58641	.23639	4.23030	.25490	3.92316	.27357	3.6553
19	.21834	4.58001	.23670	4.22481	.25521	3.91839	.27388	3.6512
20	.21864	4.57363	.23700	4.21933	.25552	3.91364	.27419	3.6470
21	.21895	4.56726	.23731	4.21387	.25583	3.90890	.27451	3.6428
22	.21925	4.56091	.23762	4.20842	.25614	3.90417	.27482	3.6387
23	.21956	4.55458	.23793	4.20298	.25645	3.89945	.27513	3.6346
24	.21986	4.54826	.23823	4.19756	.25676	3.89474	.27545	3.6304
25	.22017	4.54196	.23854	4.19215	.25707	3.89004	.27576	3.6263
26	.22047	4.53568	.23885	4.18675	.25738	3.88536	.27607	3.6222
27	.22078	4.52941	.23916	4.18137	.25769	3.88068	.27638	3.6181
28	.22108	4.52316	.23946	4.17600	.25800	3.87601	.27670	3.6140
29	.22139	4.51693	.23977	4.17064	.25831	3.87136	.27701	3.6099
30	.22169	4.51071	.24008	4.16530	.25862	3.86671	.27732	3.6058
31	.22200	4.50451	.24039	4.15997	.25893	3.86208	.27764	3.6018
32	.22231	4.49832	.24069	4.15465	.25924	3.85745	.27795	3.5977
33	.22261	4.49215	.24100	4.14934	.25955	3.85284	.27826	3.5937
34	.22292	4.48600	.24131	4.14405	.25986	3.84824	.27858	3.5896
35	.22322	4.47986	.24162	4.13877	.26017	3.84364	.27889	3.5856
36	.22353	4.47374	.24193	4.13350	.26048	3.83906	.27921	3.5815
37	.22383	4.46764	.24223	4.12825	.26079	3.83449	.27952	3.5775
38	.22414	4.46155	.24254	4.12301	.26110	3.82992	.27983	3.5735
39	.22444	4.45548	.24285	4.11778	.26141	3.82537	.28015	3.5695
40	.22475	4.44942	.24316	4.11256	.26172	3.82083	.28046	3.5655
41	.22505	4.44338	.24347	4.10736	.26203	3.81630	.28077	3.5615
42	.22536	4.43735	.24377	4.10216	.26235	3.81177	.28109	3.5576
43	.22567	4.43134	.24408	4.09699	.26266	3.80726	.28140	3.5536
44	.22597	4.42534	.24439	4.09182	.26297	3.80276	.28172	3.5496
45	.22628	4.41936	.24470	4.08666	.26328	3.79827	.28203	3.5457
46	.22658	4.41340	.24501	4.08152	.26359	3.79378	.28234	3.5417
47	.22689	4.40745	.24532	4.07639	.26390	3.78931	.28266	3.5378
48	.22719	4.40152	.24562	4.07127	.26421	3.78485	.28297	3.5339
49	.22750	4.39560	.24593	4.06616	.26452	3.78040	.28329	3.5300
50	.22781	4.38969	.24624	4.06107	.26483	3.77595	.28360	3.5260
51	.22811	4.38381	.24655	4.05599	.26515	3.77152	.28391	3.5221
52	.22842	4.37793	.24686	4.05092	.26546	3.76709	.28423	3.5182
53	.22872	4.37207	.24717	4.04586	.26577	3.76268	.28454	3.5144
54	.22903	4.36623	.24747	4.04081	.26608	3.75828	.28486	3.5105
55	.22934	4.36040	.24778	4.03578	.26639	3.75388	.28517	3.5066
56	.22964	4.35459	.24809	4.03076	.26670	3.74950	.28549	3.5027
57	.22995	4.34879	.24840	4.02574	.26701	3.74512	.28580	3.4989
58	.23026	4.34300	.24871	4.02074	.26733	3.74075	.28612	3.4950
59	.23056	4.33723	.24902	4.01576	.26764	3.73640	.28643	3.4912
60	.23087	4.33148	.24933	4.01078	.26795	3.73205	.28675	3.4874
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.
	77°		76°		75°		74°	

′	16° Tan.	16° Co-tan.	17° Tan.	17° Co-tan.	18° Tan.	18° Co-tan.	19° Tan.	19° Co-tan.	′
0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	59
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	58
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	57
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	56
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	54
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	52
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	46
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	45
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	39
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	33
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	27
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24
37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23
38	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22
39	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20
41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19
42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18
43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17
44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16
45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15
46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14
47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13
48	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12
49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11
50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10
51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9
52	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8
53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7
54	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6
55	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5
56	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4
57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3
58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
59	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1
60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0
′	73° Co-tan.	73° Tan.	72° Co-tan.	72° Tan.	71° Co-tan.	71° Tan.	70° Co-tan.	70° Tan.	′

′	20° Tan.	20° Co-tan.	21° Tan.	21° Co-tan.	22° Tan.	22° Co-tan.	23° Tan.	23° Co-tan.	′
0	.36397	2.74748	.38386	2.60509	.40403	2.47509	.42447	2.35585	60
1	.36430	2.74499	.38420	2.60283	.40436	2.47302	.42482	2.35395	59
2	.36463	2.74251	.38453	2.60057	.40470	2.47095	.42516	2.35205	58
3	.36496	2.74004	.38487	2.59831	.40504	2.46888	.42551	2.35015	57
4	.36529	2.73756	.38520	2.59606	.40538	2.46682	.42585	2.34825	56
5	.36562	2.73509	.38553	2.59381	.40572	2.46476	.42619	2.34636	55
6	.36595	2.73263	.38587	2.59156	.40606	2.46270	.42654	2.34447	54
7	.36628	2.73017	.38620	2.58932	.40640	2.46065	.42688	2.34258	53
8	.36661	2.72771	.38654	2.58708	.40674	2.45860	.42722	2.34069	52
9	.36694	2.72526	.38687	2.58484	.40707	2.45655	.42757	2.33881	51
10	.36727	2.72281	.38721	2.58261	.40741	2.45451	.42791	2.33693	50
11	.36760	2.72036	.38754	2.58038	.40775	2.45246	.42826	2.33505	49
12	.36793	2.71792	.38787	2.57815	.40809	2.45043	.42860	2.33317	48
13	.36826	2.71548	.38821	2.57593	.40843	2.44839	.42894	2.33130	47
14	.36859	2.71305	.38854	2.57371	.40877	2.44636	.42929	2.32943	46
15	.36892	2.71062	.38888	2.57150	.40911	2.44433	.42963	2.32756	45
16	.36925	2.70819	.38921	2.56928	.40945	2.44230	.42998	2.32570	44
17	.36958	2.70577	.38955	2.56707	.40979	2.44027	.43032	2.32383	43
18	.36991	2.70335	.38988	2.56487	.41013	2.43825	.43067	2.32197	42
19	.37024	2.70094	.39022	2.56266	.41047	2.43623	.43101	2.32012	41
20	.37057	2.69853	.39055	2.56046	.41081	2.43422	.43136	2.31826	40
21	.37090	2.69612	.39089	2.55826	.41115	2.43220	.43170	2.31641	39
22	.37123	2.69371	.39122	2.55608	.41149	2.43019	.43205	2.31456	38
23	.37157	2.69131	.39156	2.55389	.41183	2.42819	.43239	2.31271	37
24	.37190	2.68892	.39190	2.55170	.41217	2.42618	.43274	2.31086	36
25	.37223	2.68653	.39223	2.54952	.41251	2.42418	.43308	2.30902	35
26	.37256	2.68414	.39257	2.54734	.41285	2.42218	.43343	2.30718	34
27	.37289	2.68175	.39290	2.54516	.41319	2.42019	.43378	2.30534	33
28	.37322	2.67937	.39324	2.54299	.41353	2.41819	.43412	2.30351	32
29	.37355	2.67700	.39357	2.54082	.41387	2.41620	.43447	2.30167	31
30	.37388	2.67462	.39391	2.53865	.41421	2.41421	.43481	2.29984	30
31	.37422	2.67225	.39425	2.53648	.41455	2.41223	.43516	2.29801	29
32	.37455	2.66989	.39458	2.53432	.41490	2.41025	.43550	2.29619	28
33	.37488	2.66752	.39492	2.53217	.41524	2.40827	.43585	2.29437	27
34	.37521	2.66516	.39526	2.53001	.41558	2.40629	.43620	2.29254	26
35	.37554	2.66281	.39559	2.52786	.41592	2.40432	.43654	2.29073	25
36	.37588	2.66046	.39593	2.52571	.41626	2.40235	.43689	2.28891	24
37	.37621	2.65811	.39626	2.52357	.41660	2.40038	.43724	2.28710	23
38	.37654	2.65576	.39660	2.52142	.41694	2.39841	.43758	2.28528	22
39	.37687	2.65342	.39694	2.51929	.41728	2.39645	.43793	2.28348	21
40	.37720	2.65109	.39727	2.51715	.41763	2.39449	.43828	2.28167	20
41	.37754	2.64875	.39761	2.51502	.41797	2.39253	.43862	2.27987	19
42	.37787	2.64642	.39795	2.51289	.41831	2.39058	.43897	2.27806	18
43	.37820	2.64410	.39829	2.51076	.41865	2.38863	.43932	2.27626	17
44	.37853	2.64177	.39862	2.50864	.41899	2.38668	.43966	2.27447	16
45	.37887	2.63945	.39896	2.50652	.41933	2.38473	.44001	2.27267	15
46	.37920	2.63714	.39930	2.50440	.41968	2.38279	.44036	2.27088	14
47	.37953	2.63483	.39963	2.50229	.42002	2.38084	.44071	2.26909	13
48	.37986	2.63252	.39997	2.50018	.42036	2.37891	.44105	2.26730	12
49	.38020	2.63021	.40031	2.49807	.42070	2.37697	.44140	2.26552	11
50	.38053	2.62791	.40065	2.49597	.42105	2.37504	.44175	2.26374	10
51	.38086	2.62561	.40098	2.49386	.42139	2.37311	.44210	2.26196	9
52	.38120	2.62332	.40132	2.49177	.42173	2.37118	.44244	2.26018	8
53	.38153	2.62103	.40166	2.48967	.42207	2.36925	.44279	2.25840	7
54	.38186	2.61874	.40200	2.48758	.42242	2.36733	.44314	2.25663	6
55	.38220	2.61646	.40234	2.48549	.42276	2.36541	.44349	2.25486	5
56	.38253	2.61418	.40267	2.48340	.42310	2.36349	.44384	2.25309	4
57	.38286	2.61190	.40301	2.48132	.42345	2.36158	.44418	2.25132	3
58	.38320	2.60963	.40335	2.47924	.42379	2.35967	.44453	2.24956	2
59	.38353	2.60736	.40369	2.47716	.42413	2.35776	.44488	2.24780	1
60	.38386	2.60509	.40403	2.47509	.42447	2.35585	.44523	2.24604	0
′	Co-tan. 69°	Tan. 69°	Co-tan. 68°	Tan. 68°	Co-tan. 67°	Tan. 67°	Co-tan. 66°	Tan. 66°	′

24°		25°		26°		27°		
Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	
.44523	2.24604	.46631	2.14451	.48773	2.05030	.50953	1.96261	60
.44558	2.24428	.46666	2.14288	.48809	2.04879	.50989	1.96120	59
.44593	2.24252	.46702	2.14125	.48845	2.04728	.51026	1.95979	58
.44627	2.24077	.46737	2.13963	.48881	2.04577	.51063	1.95838	57
.44662	2.23902	.46772	2.13801	.48917	2.04426	.51099	1.95698	56
.44697	2.23727	.46808	2.13639	.48953	2.04276	.51136	1.95557	55
.44732	2.23553	.46843	2.13477	.48989	2.04125	.51173	1.95417	54
.44767	2.23378	.46879	2.13316	.49026	2.03975	.51209	1.95277	53
.44802	2.23204	.46914	2.13154	.49062	2.03825	.51246	1.95137	52
.44837	2.23030	.46950	2.12993	.49098	2.03675	.51283	1.94997	51
.44872	2.22857	.46985	2.12832	.49134	2.03526	.51319	1.94858	50
.44907	2.22683	.47021	2.12671	.49170	2.03376	.51356	1.94718	49
.44942	2.22510	.47056	2.12511	.49206	2.03227	.51393	1.94579	48
.44977	2.22337	.47092	2.12350	.49242	2.03078	.51430	1.94440	47
.45012	2.22164	.47128	2.12190	.49278	2.02929	.51467	1.94301	46
.45047	2.21992	.47163	2.12030	.49315	2.02780	.51503	1.94162	45
.45082	2.21819	.47199	2.11871	.49351	2.02631	.51540	1.94023	44
.45117	2.21647	.47234	2.11711	.49387	2.02483	.51577	1.93885	43
.45152	2.21475	.47270	2.11552	.49423	2.02335	.51614	1.93746	42
.45187	2.21304	.47305	2.11392	.49459	2.02187	.51651	1.93608	41
.45222	2.21132	.47341	2.11233	.49495	2.02039	.51688	1.93470	40
.45257	2.20961	.47377	2.11075	.49532	2.01891	.51724	1.93332	39
.45292	2.20790	.47412	2.10916	.49568	2.01743	.51761	1.93195	38
.45327	2.20619	.47448	2.10758	.49604	2.01596	.51798	1.93057	37
.45362	2.20449	.47483	2.10600	.49640	2.01449	.51835	1.92920	36
.45397	2.20278	.47519	2.10442	.49677	2.01302	.51872	1.92782	35
.45432	2.20108	.47555	2.10284	.49713	2.01155	.51909	1.92645	34
.45467	2.19938	.47590	2.10126	.49749	2.01008	.51946	1.92508	33
.45502	2.19769	.47626	2.09969	.49786	2.00862	.51983	1.92371	32
.45537	2.19599	.47662	2.09811	.49822	2.00715	.52020	1.92235	31
.45573	2.19430	.47698	2.09654	.49858	2.00569	.52057	1.92098	30
.45608	2.19261	.47733	2.09498	.49894	2.00423	.52094	1.91962	29
.45643	2.19092	.47769	2.09341	.49931	2.00277	.52131	1.91826	28
.45678	2.18923	.47805	2.09184	.49967	2.00131	.52168	1.91690	27
.45713	2.18755	.47840	2.09028	.50004	1.99986	.52205	1.91554	26
.45748	2.18587	.47876	2.08872	.50040	1.99841	.52242	1.91418	25
.45784	2.18419	.47912	2.08716	.50076	1.99695	.52279	1.91282	24
.45819	2.18251	.47948	2.08560	.50113	1.99550	.52316	1.91147	23
.45854	2.18084	.47984	2.08405	.50149	1.99406	.52353	1.91012	22
.45889	2.17916	.48019	2.08250	.50185	1.99261	.52390	1.90876	21
.45924	2.17749	.48055	2.08094	.50222	1.99116	.52427	1.90741	20
.45960	2.17582	.48091	2.07939	.50258	1.98972	.52464	1.90607	19
.45995	2.17416	.48127	2.07785	.50295	1.98828	.52501	1.90472	18
.46030	2.17249	.48163	2.07630	.50331	1.98684	.52538	1.90337	17
.46065	2.17083	.48198	2.07476	.50368	1.98540	.52575	1.90203	16
.46101	2.16917	.48234	2.07321	.50404	1.98396	.52613	1.90069	15
.46136	2.16751	.48270	2.07167	.50441	1.98253	.52650	1.89935	14
.46171	2.16585	.48306	2.07014	.50477	1.98110	.52687	1.89801	13
.46206	2.16420	.48342	2.06860	.50514	1.97966	.52724	1.89667	12
.46242	2.16255	.48378	2.06706	.50550	1.97823	.52761	1.89533	11
.46277	2.16090	.48414	2.06553	.50587	1.97680	.52798	1.89400	10
.46312	2.15925	.48450	2.06400	.50623	1.97538	.52836	1.89266	9
.46348	2.15760	.48486	2.06247	.50660	1.97395	.52873	1.89133	8
.46383	2.15596	.48521	2.06094	.50696	1.97253	.52910	1.89000	7
.46418	2.15432	.48557	2.05942	.50733	1.97111	.52947	1.88867	6
.46454	2.15268	.48593	2.05790	.50769	1.96969	.52984	1.88734	5
.46489	2.15104	.48629	2.05637	.50806	1.96827	.53022	1.88602	4
.46525	2.14940	.48665	2.05485	.50843	1.96685	.53059	1.88469	3
.46560	2.14777	.48701	2.05333	.50879	1.96544	.53096	1.88337	2
.46595	2.14614	.48737	2.05182	.50916	1.96402	.53134	1.88205	1
.46631	2.14451	.48773	2.05030	.50953	1.96261	.53171	1.88073	0
Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	
65°		64°		63°		62°		

	28°		29°		30°		31°		
′	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	′
0	.53171	1.88073	.55431	1.80405	.57735	1.73205	.60086	1.66428	60
1	.53208	1.87941	.55469	1.80281	.57774	1.73089	.60126	1.66318	59
2	.53246	1.87809	.55507	1.80158	.57813	1.72973	.60165	1.66209	58
3	.53283	1.87677	.55545	1.80034	.57851	1.72857	.60205	1.66099	57
4	.53320	1.87546	.55583	1.79911	.57890	1.72741	.60245	1.65990	56
5	.53358	1.87415	.55621	1.79788	.57929	1.72625	.60284	1.65881	55
6	.53395	1.87283	.55659	1.79665	.57968	1.72509	.60324	1.65772	54
7	.53432	1.87152	.55697	1.79542	.58007	1.72393	.60364	1.65663	53
8	.53470	1.87021	.55736	1.79419	.58046	1.72278	.60403	1.65554	52
9	.53507	1.86891	.55774	1.79296	.58085	1.72163	.60443	1.65445	51
10	.53545	1.86760	.55812	1.79174	.58124	1.72047	.60483	1.65337	50
11	.53582	1.86630	.55850	1.79051	.58162	1.71932	.60522	1.65228	49
12	.53620	1.86499	.55888	1.78929	.58201	1.71817	.60562	1.65120	48
13	.53657	1.86369	.55926	1.78807	.58240	1.71702	.60602	1.65011	47
14	.53694	1.86239	.55964	1.78685	.58279	1.71588	.60642	1.64903	46
15	.53732	1.86109	.56003	1.78563	.58318	1.71473	.60681	1.64795	45
16	.53769	1.85979	.56041	1.78441	.58357	1.71358	.60721	1.64687	44
17	.53807	1.85850	.56079	1.78319	.58396	1.71244	.60761	1.64579	43
18	.53844	1.85720	.56117	1.78198	.58435	1.71129	.60801	1.64471	42
19	.53882	1.85591	.56156	1.78077	.58474	1.71015	.60841	1.64363	41
20	.53920	1.85462	.56194	1.77955	.58513	1.70901	.60881	1.64256	40
21	.53957	1.85333	.56232	1.77834	.58552	1.70787	.60921	1.64148	39
22	.53995	1.85204	.56270	1.77713	.58591	1.70673	.60960	1.64041	38
23	.54032	1.85075	.56309	1.77592	.58631	1.70560	.61000	1.63934	37
24	.54070	1.84946	.56347	1.77471	.58670	1.70446	.61040	1.63826	36
25	.54107	1.84818	.56385	1.77351	.58709	1.70332	.61080	1.63719	35
26	.54145	1.84689	.56424	1.77230	.58748	1.70219	.61120	1.63612	34
27	.54183	1.84561	.56462	1.77110	.58787	1.70106	.61160	1.63505	33
28	.54220	1.84433	.56501	1.76990	.58826	1.69992	.61200	1.63398	32
29	.54258	1.84305	.56539	1.76869	.58865	1.69879	.61240	1.63292	31
30	.54296	1.84177	.56577	1.76749	.58905	1.69766	.61280	1.63185	30
31	.54333	1.84049	.56616	1.76629	.58944	1.69653	.61320	1.63079	29
32	.54371	1.83922	.56654	1.76510	.58983	1.69541	.61360	1.62972	28
33	.54409	1.83794	.56693	1.76390	.59022	1.69428	.61400	1.62866	27
34	.54446	1.83667	.56731	1.76271	.59061	1.69316	.61440	1.62760	26
35	.54484	1.83540	.56769	1.76151	.59101	1.69203	.61480	1.62654	25
36	.54522	1.83413	.56808	1.76032	.59140	1.69091	.61520	1.62548	24
37	.54560	1.83286	.56846	1.75913	.59179	1.68979	.61561	1.62442	23
38	.54597	1.83159	.56885	1.75794	.59218	1.68866	.61601	1.62336	22
39	.54635	1.83033	.56923	1.75675	.59258	1.68754	.61641	1.62230	21
40	.54673	1.82906	.56962	1.75556	.59297	1.68643	.61681	1.62125	20
41	.54711	1.82780	.57000	1.75437	.59336	1.68531	.61721	1.62019	19
42	.54748	1.82654	.57039	1.75319	.59376	1.68419	.61761	1.61914	18
43	.54786	1.82528	.57078	1.75200	.59415	1.68308	.61801	1.61808	17
44	.54824	1.82402	.57116	1.75082	.59454	1.68196	.61842	1.61703	16
45	.54862	1.82276	.57155	1.74964	.59494	1.68085	.61882	1.61598	15
46	.54900	1.82150	.57193	1.74846	.59533	1.67974	.61922	1.61493	14
47	.54938	1.82025	.57232	1.74728	.59573	1.67863	.61962	1.61388	13
48	.54975	1.81899	.57271	1.74610	.59612	1.67752	.62003	1.61283	12
49	.55013	1.81774	.57309	1.74492	.59651	1.67641	.62043	1.61179	11
50	.55051	1.81649	.57348	1.74375	.59691	1.67530	.62083	1.61074	10
51	.55089	1.81524	.57386	1.74257	.59730	1.67419	.62124	1.60970	9
52	.55127	1.81399	.57425	1.74140	.59770	1.67309	.62164	1.60865	8
53	.55165	1.81274	.57464	1.74022	.59809	1.67198	.62204	1.60761	7
54	.55203	1.81150	.57503	1.73905	.59849	1.67088	.62245	1.60657	6
55	.55241	1.81025	.57541	1.73788	.59888	1.66978	.62285	1.60553	5
56	.55279	1.80901	.57580	1.73671	.59928	1.66867	.62325	1.60449	4
57	.55317	1.80777	.57619	1.73555	.59967	1.66757	.62366	1.60345	3
58	.55355	1.80653	.57657	1.73438	.60007	1.66647	.62406	1.60241	2
59	.55393	1.80529	.57696	1.73321	.60046	1.66538	.62446	1.60137	1
60	.55431	1.80405	.57735	1.73205	.60086	1.66428	.62487	1.60033	0
′	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
	61°		60°		59°		58°		

32°		33°		34°		35°		
Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	′
.62487	1.60033	.64941	1.53986	.67451	1.48256	.70021	1.42815	60
.62527	1.59930	.64982	1.53888	.67493	1.48163	.70064	1.42726	59
.62568	1.59826	.65023	1.53791	.67536	1.48070	.70107	1.42638	58
.62608	1.59723	.65065	1.53693	.67578	1.47977	.70151	1.42550	57
.62649	1.59620	.65106	1.53595	.67620	1.47885	.70194	1.42462	56
.62689	1.59517	.65148	1.53497	.67663	1.47792	.70238	1.42374	55
.62730	1.59414	.65189	1.53400	.67705	1.47699	.70281	1.42286	54
.62770	1.59311	.65231	1.53302	.67748	1.47607	.70325	1.42198	53
.62811	1.59208	.65272	1.53205	.67790	1.47514	.70368	1.42110	52
.62852	1.59105	.65314	1.53107	.67832	1.47422	.70412	1.42022	51
.62892	1.59002	.65355	1.53010	.67875	1.47330	.70455	1.41934	50
.62933	1.58900	.65397	1.52913	.67917	1.47238	.70499	1.41847	49
.62973	1.58797	.65438	1.52816	.67960	1.47146	.70542	1.41759	48
.63014	1.58695	.65480	1.52719	.68002	1.47053	.70586	1.41672	47
.63055	1.58593	.65521	1.52622	.68045	1.46962	.70629	1.41584	46
.63095	1.58490	.65563	1.52525	.68088	1.46870	.70673	1.41497	45
.63136	1.58388	.65604	1.52429	.68130	1.46778	.70717	1.41409	44
.63177	1.58286	.65646	1.52332	.68173	1.46686	.70760	1.41322	43
.63217	1.58184	.65688	1.52235	.68215	1.46595	.70804	1.41235	42
.63258	1.58083	.65729	1.52139	.68258	1.46503	.70848	1.41148	41
.63299	1.57981	.65771	1.52043	.68301	1.46411	.70891	1.41061	40
.63340	1.57879	.65813	1.51946	.68343	1.46320	.70935	1.40974	39
.63380	1.57778	.65854	1.51850	.68386	1.46229	.70979	1.40887	38
.63421	1.57676	.65896	1.51754	.68429	1.46137	.71023	1.40800	37
.63462	1.57575	.65938	1.51658	.68471	1.46046	.71066	1.40714	36
.63503	1.57474	.65980	1.51562	.68514	1.45955	.71110	1.40627	35
.63544	1.57372	.66021	1.51466	.68557	1.45864	.71154	1.40540	34
.63584	1.57271	.66063	1.51370	.68600	1.45773	.71198	1.40454	33
.63625	1.57170	.66105	1.51275	.68642	1.45682	.71242	1.40367	32
.63666	1.57069	.66147	1.51179	.68685	1.45592	.71285	1.40281	31
.63707	1.56969	.66189	1.51084	.68728	1.45501	.71329	1.40195	30
.63748	1.56868	.66230	1.50988	.68771	1.45410	.71373	1.40109	29
.63789	1.56767	.66272	1.50893	.68814	1.45320	.71417	1.40022	28
.63830	1.56667	.66314	1.50797	.68857	1.45229	.71461	1.39936	27
.63871	1.56566	.66356	1.50702	.68900	1.45139	.71505	1.39850	26
.63912	1.56466	.66398	1.50607	.68942	1.45049	.71549	1.39764	25
.63953	1.56366	.66440	1.50512	.68985	1.44958	.71593	1.39679	24
.63994	1.56265	.66482	1.50417	.69028	1.44868	.71637	1.39593	23
.64035	1.56165	.66524	1.50322	.69071	1.44778	.71681	1.39507	22
.64076	1.56065	.66566	1.50228	.69114	1.44688	.71725	1.39421	21
.64117	1.55966	.66608	1.50133	.69157	1.44598	.71769	1.39336	20
.64158	1.55866	.66650	1.50038	.69200	1.44508	.71813	1.39250	19
.64199	1.55765	.66692	1.49944	.69243	1.44418	.71857	1.39165	18
.64240	1.55666	.66734	1.49849	.69286	1.44329	.71901	1.39079	17
.64281	1.55567	.66776	1.49755	.69329	1.44239	.71946	1.38994	16
.64322	1.55467	.66818	1.49661	.69372	1.44149	.71990	1.38909	15
.64363	1.55368	.66860	1.49566	.69416	1.44060	.72034	1.38824	14
.64404	1.55269	.66902	1.49472	.69459	1.43970	.72078	1.38738	13
.64446	1.55170	.66944	1.49378	.69502	1.43881	.72122	1.38653	12
.64487	1.55071	.66986	1.49284	.69545	1.43792	.72167	1.38568	11
.64528	1.54972	.67028	1.49190	.69588	1.43703	.72211	1.38484	10
.64569	1.54873	.67071	1.49097	.69631	1.43614	.72255	1.38399	9
.64610	1.54774	.67113	1.49003	.69675	1.43525	.72299	1.38314	8
.64652	1.54675	.67155	1.48909	.69718	1.43436	.72344	1.38229	7
.64693	1.54576	.67197	1.48816	.69761	1.43347	.72388	1.38145	6
.64734	1.54478	.67239	1.48722	.69804	1.43258	.72432	1.38060	5
.64775	1.54379	.67282	1.48629	.69847	1.43169	.72477	1.37976	4
.64817	1.54281	.67324	1.48536	.69891	1.43080	.72521	1.37891	3
.64858	1.54183	.67366	1.48442	.69934	1.42992	.72565	1.37807	2
.64899	1.54085	.67409	1.48349	.69977	1.42903	.72610	1.37722	1
.64941	1.53986	.67451	1.48256	.70021	1.42815	.72654	1.37638	0
Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
57°		56°		55°		54°		

′	36° Tan	36° Co-tan	37° Tan.	37° Co-tan	38° Tan.	38° Co-tan	39° Tan	39° Co-tan	′
0	72654	1.37638	75355	1.32704	78129	1.27994	.80978	1.23490	60
1	72699	1.37554	75401	1.32624	78175	1.27917	.81027	1.23416	59
2	72743	1.37470	75447	1.32544	78222	1.27841	.81075	1.23343	58
3	72788	1.37386	75492	1.32464	78269	1.27764	.81123	1.23270	57
4	72832	1.37302	75538	1.32384	78316	1.27688	.81171	1.23196	56
5	72877	1.37218	75584	1.32304	78363	1.27611	.81220	1.23123	55
6	72921	1.37134	75629	1.32224	78410	1.27535	.81268	1.23050	54
7	72966	1.37050	75675	1.32144	78457	1.27458	.81316	1.22977	53
8	73010	1.36967	75721	1.32064	78504	1.27382	.81364	1.22904	52
9	73055	1.36883	75767	1.31984	78551	1.27306	.81413	1.22831	51
10	73100	1.36800	75812	1.31904	78598	1.27230	.81461	1.22758	50
11	73144	1.36716	75858	1.31825	78645	1.27153	.81510	1.22685	49
12	73189	1.36633	75904	1.31745	78692	1.27077	.81558	1.22612	48
13	73234	1.36549	75950	1.31666	78739	1.27001	.81606	1.22539	47
14	73278	1.36466	75996	1.31586	78786	1.26925	.81655	1.22467	46
15	73323	1.36383	76042	1.31507	78834	1.26849	.81703	1.22394	45
16	73368	1.36300	76088	1.31427	78881	1.26774	.81752	1.22321	44
17	73413	1.36217	76134	1.31348	78928	1.26698	.81800	1.22249	43
18	73457	1.36133	76180	1.31269	78975	1.26622	.81849	1.22176	42
19	73502	1.36051	76226	1.31190	79022	1.26546	.81898	1.22104	41
20	73547	1.35968	76272	1.31110	79070	1.26471	.81946	1.22031	40
21	73592	1.35885	76318	1.31031	.79117	1.26395	.81995	1.21959	39
22	73637	1.35802	76364	1.30952	.79164	1.26319	.82044	1.21886	38
23	73681	1.35719	76410	1.30873	.79212	1.26244	.82092	1.21814	37
24	73726	1.35637	76456	1.30795	.79259	1.26169	.82141	1.21742	36
25	.73771	1.35554	76502	1.30716	79306	1.26093	.82190	1.21670	35
26	73816	1.35472	.76548	1.30637	79354	1.26018	.82238	1.21598	34
27	73861	1.35389	76594	1.30558	.79401	1.25943	.82287	1.21526	33
28	73906	1.35307	76640	1.30480	79449	1.25867	.82336	1.21454	32
29	73951	1.35224	76686	1.30401	79496	1.25792	.82385	1.21382	31
30	73996	1.35142	76733	1.30323	.79544	1.25717	.82434	1.21310	30
31	74041	1.35060	76779	1.30244	.79591	1.25642	.82483	1.21238	29
32	74086	1.34978	76825	1.30166	.79639	1.25567	.82531	1.21166	28
33	74131	1.34896	.76871	1.30087	.79686	1.25492	.82580	1.21094	27
34	74176	1.34814	76918	1.30009	.79734	1.25417	.82629	1.21023	26
35	74221	1.34732	76964	1.29931	.79781	1.25343	.82678	1.20951	25
36	74267	1.34650	77010	1.29853	79829	1.25268	.82727	1.20879	24
37	74312	1.34568	77057	1.29775	79877	1.25193	.82776	1.20808	23
38	74357	1.34487	77103	1.29696	79924	1.25118	.82825	1.20736	22
39	74402	1.34405	77149	1.29618	79972	1.25044	.82874	1.20665	21
40	74447	1.34323	77196	1.29541	.80020	1.24969	.82923	1.20593	20
41	74492	1.34242	77242	1.29463	.80067	1.24895	.82972	1.20522	19
42	74538	1.34160	77289	1.29385	.80115	1.24820	.83022	1.20451	18
43	74583	1.34079	77335	1.29307	.80163	1.24746	.83071	1.20379	17
44	74628	1.33998	77382	1.29229	.80211	1.24672	.83120	1.20308	16
45	74674	1.33916	77428	1.29152	.80258	1.24597	.83169	1.20237	15
46	74719	1.33835	77475	1.29074	.80306	1.24523	.83218	1.20166	14
47	74764	1.33754	77521	1.28997	.80354	1.24449	.83268	1.20095	13
48	74810	1.33673	77568	1.28919	.80402	1.24375	.83317	1.20024	12
49	74855	1.33592	77615	1.28842	.80450	1.24301	.83366	1.19953	11
50	74900	1.33511	77661	1.28764	.80498	1.24227	.83415	1.19882	10
51	74946	1.33430	77708	1.28687	.80546	1.24153	.83465	1.19811	9
52	74991	1.33349	77754	1.28610	.80594	1.24079	.83514	1.19740	8
53	75037	1.33268	.77801	1.28533	.80642	1.24005	.83564	1.19669	7
54	75082	1.33187	77848	1.28456	.80690	1.23931	.83613	1.19599	6
55	75128	1.33107	.77895	1.28379	.80738	1.23858	.83662	1.19528	5
56	75173	1.33026	77941	1.28302	.80786	1.23784	.83712	1.19457	4
57	75219	1.32946	77988	1.28225	.80834	1.23710	.83761	1.19387	3
58	75264	1.32865	78035	1.28148	.80882	1.23637	.83811	1.19316	2
59	75310	1.32785	78082	1.28071	.80930	1.23563	.83860	1.19246	1
60	.75355	1.32704	.78129	1.27994	.80978	1.23490	.83910	1.19175	0
′	Co-tan. 53°	Tan. 53°	Co-tan. 52°	Tan. 52°	Co-tan. 51°	Tan. 51°	Co-tan. 50°	Tan. 50°	′

40°		41°		42°		43°		
Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	′
.83910	1.19175	.86929	1.15037	.90040	1.11061	.93252	1.07237	60
.83960	1.19105	.86980	1.14969	.90093	1.10996	.93306	1.07174	59
.84009	1.19035	.87031	1.14902	.90146	1.10931	.93360	1.07112	58
.84059	1.18964	.87082	1.14834	.90199	1.10867	.93415	1.07049	57
.84108	1.18894	.87133	1.14767	.90251	1.10802	.93469	1.06987	56
.84158	1.18824	.87184	1.14699	.90304	1.10737	.93524	1.06925	55
.84208	1.18754	.87236	1.14632	.90357	1.10672	.93578	1.06862	54
.84258	1.18684	.87287	1.14565	.90410	1.10607	.93633	1.06800	53
.84307	1.18614	.87338	1.14498	.90463	1.10543	.93688	1.06738	52
.84357	1.18544	.87389	1.14430	.90516	1.10478	.93742	1.06676	51
.84407	1.18474	.87441	1.14363	.90569	1.10414	.93797	1.06613	50
.84457	1.18404	.87492	1.14296	.90621	1.10349	.93852	1.06551	49
.84507	1.18334	.87543	1.14229	.90674	1.10285	.93906	1.06489	48
.84556	1.18264	.87595	1.14162	.90727	1.10220	.93961	1.06427	47
.84606	1.18194	.87646	1.14095	.90781	1.10156	.94016	1.06365	46
.84656	1.18125	.87698	1.14028	.90834	1.10091	.94071	1.06303	45
.84706	1.18055	.87749	1.13961	.90887	1.10027	.94125	1.06241	44
.84756	1.17986	.87801	1.13894	.90940	1.09963	.94180	1.06179	43
.84806	1.17916	.87852	1.13828	.90993	1.09899	.94235	1.06117	42
.84856	1.17846	.87904	1.13761	.91046	1.09834	.94290	1.06056	41
.84906	1.17777	.87955	1.13694	.91099	1.09770	.94345	1.05994	40
.84956	1.17708	.88007	1.13627	.91153	1.09706	.94400	1.05932	39
.85006	1.17638	.88059	1.13561	.91206	1.09642	.94455	1.05870	38
.85057	1.17569	.88110	1.13494	.91259	1.09578	.94510	1.05809	37
.85107	1.17500	.88162	1.13428	.91313	1.09514	.94565	1.05747	36
.85157	1.17430	.88214	1.13361	.91366	1.09450	.94620	1.05685	35
.85207	1.17361	.88265	1.13295	.91419	1.09386	.94676	1.05624	34
.85257	1.17292	.88317	1.13228	.91473	1.09322	.94731	1.05562	33
.85308	1.17223	.88369	1.13162	.91526	1.09258	.94786	1.05501	32
.85358	1.17154	.88421	1.13096	.91580	1.09195	.94841	1.05439	31
.85408	1.17085	.88473	1.13029	.91633	1.09131	.94896	1.05378	30
.85458	1.17016	.88524	1.12963	.91687	1.09067	.94952	1.05317	29
.85509	1.16947	.88576	1.12897	.91740	1.09003	.95007	1.05255	28
.85559	1.16878	.88628	1.12831	.91794	1.08940	.95062	1.05194	27
.85610	1.16809	.88680	1.12765	.91847	1.08876	.95118	1.05133	26
.85660	1.16741	.88732	1.12699	.91901	1.08813	.95173	1.05072	25
.85710	1.16672	.88784	1.12633	.91955	1.08749	.95229	1.05010	24
.85761	1.16603	.88836	1.12567	.92008	1.08686	.95284	1.04949	23
.85811	1.16535	.88888	1.12501	.92062	1.08622	.95340	1.04888	22
.85862	1.16466	.88940	1.12435	.92116	1.08559	.95395	1.04827	21
.85912	1.16398	.88992	1.12369	.92170	1.08496	.95451	1.04766	20
.85963	1.16329	.89045	1.12303	.92224	1.08432	.95506	1.04705	19
.86014	1.16261	.89097	1.12238	.92277	1.08369	.95562	1.04644	18
.86064	1.16192	.89149	1.12172	.92331	1.08306	.95618	1.04583	17
.86115	1.16124	.89201	1.12106	.92385	1.08243	.95673	1.04522	16
.86166	1.16056	.89253	1.12041	.92439	1.08179	.95729	1.04461	15
.86216	1.15987	.89306	1.11975	.92493	1.08116	.95785	1.04401	14
.86267	1.15919	.89358	1.11909	.92547	1.08053	.95841	1.04340	13
.86318	1.15851	.89410	1.11844	.92601	1.07990	.95897	1.04279	12
.86368	1.15783	.89463	1.11778	.92655	1.07927	.95952	1.04218	11
.86419	1.15715	.89515	1.11713	.92709	1.07864	.96008	1.04158	10
.86470	1.15647	.89567	1.11648	.92763	1.07801	.96064	1.04097	9
.86521	1.15579	.89620	1.11582	.92817	1.07738	.96120	1.04036	8
.86572	1.15511	.89672	1.11517	.92872	1.07676	.96176	1.03976	7
.86623	1.15443	.89725	1.11452	.92926	1.07613	.96232	1.03915	6
.86674	1.15375	.89777	1.11387	.92980	1.07550	.96288	1.03855	5
.86725	1.15308	.89830	1.11321	.93034	1.07487	.96344	1.03794	4
.86776	1.15240	.89883	1.11256	.93088	1.07425	.96400	1.03734	3
.86827	1.15172	.89935	1.11191	.93143	1.07362	.96457	1.03674	2
.86878	1.15104	.89988	1.11126	.93197	1.07299	.96513	1.03613	1
.86929	1.15037	.90040	1.11061	.93252	1.07237	.96569	1.03553	0
Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	Co-tan.	Tan.	′
49°		48°		47°		46°		

′	44° Tan.	44° Co-tan.	′	′	44° Tan.	44° Co-tan.	′	′	44° Tan.	44° Co-tan.	′
0	.96569	1.03553	60	21	.97756	1.02295	39	41	.98901	1.01112	19
1	.96625	1.03493	59	22	.97813	1.02236	38	42	.98958	1.01053	18
2	.96681	1.03433	58	23	.97870	1.02176	37	43	.99016	1.00994	17
3	.96738	1.03372	57	24	.97927	1.02117	36	44	.99073	1.00935	16
4	.96794	1.03312	56	25	.97984	1.02057	35	45	.99131	1.00876	15
5	.96850	1.03252	55	26	.98041	1.01998	34	46	.99189	1.00818	14
6	.96907	1.03192	54	27	.98098	1.01939	33	47	.99247	1.00759	13
7	.96963	1.03132	53	28	.98155	1.01879	32	48	.99304	1.00701	12
8	.97020	1.03072	52	29	.98213	1.01820	31	49	.99362	1.00642	11
9	.97076	1.03012	51	30	.98270	1.01761	30	50	.99420	1.00583	10
10	.97133	1.02952	50	31	.98327	1.01702	29	51	.99478	1.00525	9
11	.97189	1.02892	49	32	.98384	1.01642	28	52	.99536	1.00467	8
12	.97246	1.02832	48	33	.98441	1.01583	27	53	.99594	1.00408	7
13	.97302	1.02772	47	34	.98499	1.01524	26	54	.99652	1.00350	6
14	.97359	1.02713	46	35	.98556	1.01465	25	55	.99710	1.00291	5
15	.97416	1.02653	45	36	.98613	1.01406	24	56	.99768	1.00233	4
16	.97472	1.02593	44	37	.98671	1.01347	23	57	.99826	1.00175	3
17	.97529	1.02533	43	38	.98728	1.01288	22	58	.99884	1.00116	2
18	.97586	1.02474	42	39	.98786	1.01229	21	59	.99942	1.00058	1
19	.97643	1.02414	41	40	.98843	1.01170	20	60	1	1	0
20	.97700	1.02355	40								
′	45° Co-tan	45° Tan.	′	′	45° Co-tan	45° Tan.	′	′	45° Co-tan	45° Tan.	′

NATURAL SINES AND COSINES

′	0° Sine	0° Cosine	′	′	0° Sine	0° Cosine	′	′	0° Sine	0° Cosine	′
0	.00000	1	60	21	.00611	.99998	39	41	.01193	.99993	19
1	.00029	1	59	22	.00640	.99998	38	42	.01222	.99993	18
2	.00058	1	58	23	.00669	.99998	37	43	.01251	.99992	17
3	.00087	1	57	24	.00698	.99998	36	44	.01280	.99992	16
4	.00116	1	56	25	.00727	.99997	35	45	.01309	.99991	15
5	.00145	1	55	26	.00756	.99997	34	46	.01338	.99991	14
6	.00175	1	54	27	.00785	.99997	33	47	.01367	.99991	13
7	.00204	1	53	28	.00814	.99997	32	48	.01396	.99990	12
8	.00233	1	52	29	.00844	.99996	31	49	.01425	.99990	11
9	.00262	1	51	30	.00873	.99996	30	50	.01454	.99989	10
10	.00291	1	50	31	.00902	.99996	29	51	.01483	.99989	9
11	.00320	.99999	49	32	.00931	.99996	28	52	.01513	.99989	8
12	.00349	.99999	48	33	.00960	.99995	27	53	.01542	.99988	7
13	.00378	.99999	47	34	.00989	.99995	26	54	.01571	.99988	6
14	.00407	.99999	46	35	.01018	.99995	25	55	.01600	.99987	5
15	.00436	.99999	45	36	.01047	.99995	24	56	.01629	.99987	4
16	.00465	.99999	44	37	.01076	.99994	23	57	.01658	.99986	3
17	.00495	.99999	43	38	.01105	.99994	22	58	.01687	.99986	2
18	.00524	.99999	42	39	.01134	.99994	21	59	.01716	.99985	1
19	.00553	.99998	41	40	.01164	.99993	20	60	.01745	.99985	0
20	.00582	.99998	40								
′	89° Cosine	89° Sine	′	′	89° Cosine	89° Sine	′	′	89° Cosine	89° Sine	′

′	1°		2°		3°		4°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.01745	.99985	.03490	.99939	.05234	.99863	.06976	.99756	60
1	.01774	.99984	.03519	.99938	.05263	.99861	.07005	.99754	59
2	.01803	.99984	.03548	.99937	.05292	.99860	.07034	.99752	58
3	.01832	.99983	.03577	.99936	.05321	.99858	.07063	.99750	57
4	.01862	.99983	.03606	.99935	.05350	.99857	.07092	.99748	56
5	.01891	.99982	.03635	.99934	.05379	.99855	.07121	.99746	55
6	.01920	.99982	.03664	.99933	.05408	.99854	.07150	.99744	54
7	.01949	.99981	.03693	.99932	.05437	.99852	.07179	.99742	53
8	.01978	.99980	.03723	.99931	.05466	.99851	.07208	.99740	52
9	.02007	.99980	.03752	.99930	.05495	.99849	.07237	.99738	51
10	.02036	.99979	.03781	.99929	.05524	.99847	.07266	.99736	50
11	.02065	.99979	.03810	.99927	.05553	.99846	.07295	.99734	49
12	.02094	.99978	.03839	.99926	.05582	.99844	.07324	.99731	48
13	.02123	.99977	.03868	.99925	.05611	.99842	.07353	.99729	47
14	.02152	.99977	.03897	.99924	.05640	.99841	.07382	.99727	46
15	.02181	.99976	.03926	.99923	.05669	.99839	.07411	.99725	45
16	.02211	.99976	.03955	.99922	.05698	.99838	.07440	.99723	44
17	.02240	.99975	.03984	.99921	.05727	.99836	.07469	.99721	43
18	.02269	.99974	.04013	.99919	.05756	.99834	.07498	.99719	42
19	.02298	.99974	.04042	.99918	.05785	.99833	.07527	.99716	41
20	.02327	.99973	.04071	.99917	.05814	.99831	.07556	.99714	40
21	.02356	.99972	.04100	.99916	.05844	.99829	.07585	.99712	39
22	.02385	.99972	.04129	.99915	.05873	.99827	.07614	.99710	38
23	.02414	.99971	.04159	.99913	.05902	.99826	.07643	.99708	37
24	.02443	.99970	.04188	.99912	.05931	.99824	.07672	.99705	36
25	.02472	.99969	.04217	.99911	.05960	.99822	.07701	.99703	35
26	.02501	.99969	.04246	.99910	.05989	.99821	.07730	.99701	34
27	.02530	.99968	.04275	.99909	.06018	.99819	.07759	.99699	33
28	.02560	.99967	.04304	.99907	.06047	.99817	.07788	.99696	32
29	.02589	.99966	.04333	.99906	.06076	.99815	.07817	.99694	31
30	.02618	.99966	.04362	.99905	.06105	.99813	.07846	.99692	30
31	.02647	.99965	.04391	.99904	.06134	.99812	.07875	.99689	29
32	.02676	.99964	.04420	.99902	.06163	.99810	.07904	.99687	28
33	.02705	.99963	.04449	.99901	.06192	.99808	.07933	.99685	27
34	.02734	.99963	.04478	.99900	.06221	.99806	.07962	.99683	26
35	.02763	.99962	.04507	.99898	.06250	.99804	.07991	.99680	25
36	.02792	.99961	.04536	.99897	.06279	.99803	.08020	.99678	24
37	.02821	.99960	.04565	.99896	.06308	.99801	.08049	.99676	23
38	.02850	.99959	.04594	.99894	.06337	.99799	.08078	.99673	22
39	.02879	.99959	.04623	.99893	.06366	.99797	.08107	.99671	21
40	.02908	.99958	.04653	.99892	.06395	.99795	.08136	.99668	20
41	.02938	.99957	.04682	.99890	.06424	.99793	.08165	.99666	19
42	.02967	.99956	.04711	.99889	.06453	.99792	.08194	.99664	18
43	.02996	.99955	.04740	.99888	.06482	.99790	.08223	.99661	17
44	.03025	.99954	.04769	.99886	.06511	.99788	.08252	.99659	16
45	.03054	.99953	.04798	.99885	.06540	.99786	.08281	.99657	15
46	.03083	.99952	.04827	.99883	.06569	.99784	.08310	.99654	14
47	.03112	.99952	.04856	.99882	.06598	.99782	.08339	.99652	13
48	.03141	.99951	.04885	.99881	.06627	.99780	.08368	.99649	12
49	.03170	.99950	.04914	.99879	.06656	.99778	.08397	.99647	11
50	.03199	.99949	.04943	.99878	.06685	.99776	.08426	.99644	10
51	.03228	.99948	.04972	.99876	.06714	.99774	.08455	.99642	9
52	.03257	.99947	.05001	.99875	.06743	.99772	.08484	.99639	8
53	.03286	.99946	.05030	.99873	.06773	.99770	.08513	.99637	7
54	.03316	.99945	.05059	.99872	.06802	.99768	.08542	.99635	6
55	.03345	[illegible]	.05088	.99870	.06831	.99766	.08571	.99632	5
56	.03374	.99943	.05117	.99869	.06860	.99764	.08600	.99630	4
57	.03403	.99942	.05146	.99867	.06889	.99762	.08629	.99627	3
58	.03432	.99941	.05175	.99866	.06918	.99760	.08658	.99625	2
59	.03461	.99940	.05205	.99864	.06947	.99758	.08687	.99622	1
60	.03490	.99939	.05234	.99863	.06976	.99756	.08716	.99619	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	88°		87°		86°		85°		

′	5°		6°		7°		8°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.08716	.99619	.10453	.99452	.12187	.99255	.13917	.99027	60
1	.08745	.99617	.10482	.99449	.12216	.99251	.13946	.99023	59
2	.08774	.99614	.10511	.99446	.12245	.99248	.13975	.99019	58
3	.08803	.99612	.10540	.99443	.12274	.99244	.14004	.99015	57
4	.08831	.99609	.10569	.99440	.12302	.99240	.14033	.99011	56
5	.08860	.99607	.10597	.99437	.12331	.99237	.14061	.99006	55
6	.08889	.99604	.10626	.99434	.12360	.99233	.14090	.99002	54
7	.08918	.99602	.10655	.99431	.12389	.99230	.14119	.98998	53
8	.08947	.99599	.10684	.99428	.12418	.99226	.14148	.98994	52
9	.08976	.99596	.10713	.99424	.12447	.99222	.14177	.98990	51
10	.09005	.99594	.10742	.99421	.12476	.99219	.14205	.98986	50
11	.09034	.99591	.10771	.99418	.12504	.99215	.14234	.98982	49
12	.09063	.99588	.10800	.99415	.12533	.99211	.14263	.98978	48
13	.09092	.99586	.10829	.99412	.12562	.99208	.14292	.98973	47
14	.09121	.99583	.10858	.99409	.12591	.99204	.14320	.98969	46
15	.09150	.99580	.10887	.99406	.12620	.99200	.14349	.98965	45
16	.09179	.99578	.10916	.99402	.12649	.99197	.14378	.98961	44
17	.09208	.99575	.10945	.99399	.12678	.99193	.14407	.98957	43
18	.09237	.99572	.10973	.99396	.12706	.99189	.14436	.98953	42
19	.09266	.99570	.11002	.99393	.12735	.99186	.14464	.98948	41
20	.09295	.99567	.11031	.99390	.12764	.99182	.14493	.98944	40
21	.09324	.99564	.11060	.99386	.12793	.99178	.14522	.98940	39
22	.09353	.99562	.11089	.99383	.12822	.99175	.14551	.98936	38
23	.09382	.99559	.11118	.99380	.12851	.99171	.14580	.98931	37
24	.09411	.99556	.11147	.99377	.12880	.99167	.14608	.98927	36
25	.09440	.99553	.11176	.99374	.12908	.99163	.14637	.98923	35
26	.09469	.99551	.11205	.99370	.12937	.99160	.14666	.98919	34
27	.09498	.99548	.11234	.99367	.12966	.99156	.14695	.98914	33
28	.09527	.99545	.11263	.99364	.12995	.99152	.14723	.98910	32
29	.09556	.99542	.11291	.99360	.13024	.99148	.14752	.98906	31
30	.09585	.99540	.11320	.99357	.13053	.99144	.14781	.98902	30
31	.09614	.99537	.11349	.99354	.13081	.99141	.14810	.98897	29
32	.09642	.99534	.11378	.99351	.13110	.99137	.14838	.98893	28
33	.09671	.99531	.11407	.99347	.13139	.99133	.14867	.98889	27
34	.09700	.99528	.11436	.99344	.13168	.99129	.14896	.98884	26
35	.09729	.99526	.11465	.99341	.13197	.99125	.14925	.98880	25
36	.09758	.99523	.11494	.99337	.13226	.99122	.14954	.98876	24
37	.09787	.99520	.11523	.99334	.13254	.99118	.14982	.98871	23
38	.09816	.99517	.11552	.99331	.13283	.99114	.15011	.98867	22
39	.09845	.99514	.11580	.99327	.13312	.99110	.15040	.98863	21
40	.09874	.99511	.11609	.99324	.13341	.99106	.15069	.98858	20
41	.09903	.99508	.11638	.99320	.13370	.99102	.15097	.98854	19
42	.09932	.99506	.11667	.99317	.13399	.99098	.15126	.98849	18
43	.09961	.99503	.11696	.99314	.13427	.99094	.15155	.98845	17
44	.09990	.99500	.11725	.99310	.13456	.99091	.15184	.98841	16
45	.10019	.99497	.11754	.99307	.13485	.99087	.15212	.98836	15
46	.10048	.99494	.11783	.99303	.13514	.99083	.15241	.98832	14
47	.10077	.99491	.11812	.99300	.13543	.99079	.15270	.98827	13
48	.10106	.99488	.11840	.99297	.13572	.99075	.15299	.98823	12
49	.10135	.99485	.11869	.99293	.13600	.99071	.15327	.98818	11
50	.10164	.99482	.11898	.99290	.13629	.99067	.15356	.98814	10
51	.10192	.99479	.11927	.99286	.13658	.99063	.15385	.98809	9
52	.10221	.99476	.11956	.99283	.13687	.99059	.15414	.98805	8
53	.10250	.99473	.11985	.99279	.13716	.99055	.15442	.98800	7
54	.10279	.99470	.12014	.99276	.13744	.99051	.15471	.98796	6
55	.10308	.99467	.12043	.99272	.13773	.99047	.15500	.98791	5
56	.10337	.99464	.12071	.99269	.13802	.99043	.15529	.98787	4
57	.10366	.99461	.12100	.99265	.13831	.99039	.15557	.98782	3
58	.10395	.99458	.12129	.99262	.13860	.99035	.15586	.98778	2
59	.10424	.99455	.12158	.99258	.13889	.99031	.15615	.98773	1
60	.10453	.99452	.12187	.99255	.13917	.99027	.15643	.98769	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	84°		83°		82°		81°		

	9°	10°		11°		12°		
	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	′
43	.98769	.17365	.98481	.19081	.98163	.20791	.97815	60
72	.98764	.17393	.98476	.19109	.98157	.20820	.97809	59
01	.98760	.17422	.98471	.19138	.98152	.20848	.97803	58
30	.98755	.17451	.98466	.19167	.98146	.20877	.97797	57
58	.98751	.17479	.98461	.19195	.98140	.20905	.97791	56
87	.98746	.17508	.98455	.19224	.98135	.20933	.97784	55
16	.98741	.17537	.98450	.19252	.98129	.20962	.97778	54
45	.98737	.17565	.98445	.19281	.98124	.20990	.97772	53
73	.98732	.17594	.98440	.19309	.98118	.21019	.97766	52
02	.98728	.17623	.98435	.19338	.98112	.21047	.97760	51
31	.98723	.17651	.98430	.19366	.98107	.21076	.97754	50
59	.98718	.17680	.98425	.19395	.98101	.21104	.97748	49
88	.98714	.17708	.98420	.19423	.98096	.21132	.97742	48
17	.98709	.17737	.98414	.19452	.98090	.21161	.97735	47
46	.98704	.17766	.98409	.19481	.98084	.21189	.97729	46
74	.98700	.17794	.98404	.19509	.98079	.21218	.97723	45
03	.98695	.17823	.98399	.19538	.98073	.21246	.97717	44
32	.98690	.17852	.98394	.19566	.98067	.21275	.97711	43
60	.98686	.17880	.98389	.19595	.98061	.21303	.97705	42
89	.98681	.17909	.98383	.19623	.98056	.21331	.97698	41
18	.98676	.17937	.98378	.19652	.98050	.21360	.97692	40
46	.98671	.17966	.98373	.19680	.98044	.21388	.97686	39
75	.98667	.17995	.98368	.19709	.98039	.21417	.97680	38
04	.98662	.18023	.98362	.19737	.98033	.21445	.97673	37
33	.98657	.18052	.98357	.19766	.98027	.21474	.97667	36
61	.98652	.18081	.98352	.19794	.98021	.21502	.97661	35
90	.98648	.18109	.98347	.19823	.98016	.21530	.97655	34
19	.98643	.18138	.98341	.19851	.98010	.21559	.97648	33
47	.98638	.18166	.98336	.19880	.98004	.21587	.97642	32
76	.98633	.18195	.98331	.19908	.97998	.21616	.97636	31
05	.98629	.18224	.98325	.19937	.97992	.21644	.97630	30
33	.98624	.18252	.98320	.19965	.97987	.21672	.97623	29
62	.98619	.18281	.98315	.19994	.97981	.21701	.97617	28
91	.98614	.18309	.98310	.20022	.97975	.21729	.97611	27
20	.98609	.18338	.98304	.20051	.97969	.21758	.97604	26
48	.98604	.18367	.98299	.20079	.97963	.21786	.97598	25
77	.98600	.18395	.98294	.20108	.97958	.21814	.97592	24
06	.98595	.18424	.98288	.20136	.97952	.21843	.97585	23
34	.98590	.18452	.98283	.20165	.97946	.21871	.97579	22
63	.98585	.18481	.98277	.20193	.97940	.21899	.97573	21
92	.98580	.18509	.98272	.20222	.97934	.21928	.97566	20
20	.98575	.18538	.98267	.20250	.97928	.21956	.97560	19
49	.98570	.18567	.98261	.20279	.97922	.21985	.97553	18
78	.98565	.18595	.98256	.20307	.97916	.22013	.97547	17
06	.98561	.18624	.98250	.20336	.97910	.22041	.97541	16
35	.98556	.18652	.98245	.20364	.97905	.22070	.97534	15
64	.98551	.18681	.98240	.20393	.97899	.22098	.97528	14
92	.98546	.18710	.98234	.20421	.97893	.22126	.97521	13
21	.98541	.18738	.98229	.20450	.97887	.22155	.97515	12
50	.98536	.18767	.98223	.20478	.97881	.22183	.97508	11
78	.98531	.18795	.98218	.20507	.97875	.22212	.97502	10
07	.98526	.18824	.98212	.20535	.97869	.22240	.97496	9
36	.98521	.18852	.98207	.20563	.97863	.22268	.97489	8
64	.98516	.18881	.98201	.20592	.97857	.22297	.97483	7
93	.98511	.18910	.98196	.20620	.97851	.22325	.97476	6
22	.98506	.18938	.98190	.20649	.97845	.22353	.97470	5
50	.98501	.18967	.98185	.20677	.97839	.22382	.97463	4
79	.98496	.18995	.98179	.20706	.97833	.22410	.97457	3
08	.98491	.19024	.98174	.20734	.97827	.22438	.97450	2
36	.98486	.19052	.98168	.20763	.97821	.22467	.97444	1
65	.98481	.19081	.98163	.20791	.97815	.22495	.97437	0
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	80°	79°		78°		77°		

′	13° Sine	13° Cosine	14° Sine	14° Cosine	15° Sine	15° Cosine	16° Sine	16° Cosine	′
0	.22495	.97437	.24192	.97030	.25882	.96593	.27564	.96126	60
1	.22523	.97430	.24220	.97023	.25910	.96585	.27592	.96118	59
2	.22552	.97424	.24249	.97015	.25938	.96578	.27620	.96110	58
3	.22580	.97417	.24277	.97008	.25966	.96570	.27648	.96102	57
4	.22608	.97411	.24305	.97001	.25994	.96562	.27676	.96094	56
5	.22637	.97404	.24333	.96994	.26022	.96555	.27704	.96086	55
6	.22665	.97398	.24362	.96987	.26050	.96547	.27731	.96078	54
7	.22693	.97391	.24390	.96980	.26079	.96540	.27759	.96070	53
8	.22722	.97384	.24418	.96973	.26107	.96532	.27787	.96062	52
9	.22750	.97378	.24446	.96966	.26135	.96524	.27815	.96054	51
10	.22778	.97371	.24474	.96959	.26163	.96517	.27843	.96046	50
11	.22807	.97365	.24503	.96952	.26191	.96509	.27871	.96037	49
12	.22835	.97358	.24531	.96945	.26219	.96502	.27899	.96029	48
13	.22863	.97351	.24559	.96937	.26247	.96494	.27927	.96021	47
14	.22892	.97345	.24587	.96930	.26275	.96486	.27955	.96013	46
15	.22920	.97338	.24615	.96923	.26303	.96479	.27983	.96005	45
16	.22948	.97331	.24644	.96916	.26331	.96471	.28011	.95997	44
17	.22977	.97325	.24672	.96909	.26359	.96463	.28039	.95989	43
18	.23005	.97318	.24700	.96902	.26387	.96456	.28067	.95981	42
19	.23033	.97311	.24728	.96894	.26415	.96448	.28095	.95972	41
20	.23062	.97304	.24756	.96887	.26443	.96440	.28123	.95964	40
21	.23090	.97298	.24784	.96880	.26471	.96433	.28150	.95956	39
22	.23118	.97291	.24813	.96873	.26500	.96425	.28178	.95948	38
23	.23146	.97284	.24841	.96866	.26528	.96417	.28206	.95940	37
24	.23175	.97278	.24869	.96858	.26556	.96410	.28234	.95931	36
25	.23203	.97271	.24897	.96851	.26584	.96402	.28262	.95923	35
26	.23231	.97264	.24925	.96844	.26612	.96394	.28290	.95915	34
27	.23260	.97257	.24954	.96837	.26640	.96386	.28318	.95907	33
28	.23288	.97251	.24982	.96829	.26668	.96379	.28346	.95898	32
29	.23316	.97244	.25010	.96822	.26696	.96371	.28374	.95890	31
30	.23345	.97237	.25038	.96815	.26724	.96363	.28402	.95882	30
31	.23373	.97230	.25066	.96807	.26752	.96355	.28429	.95874	29
32	.23401	.97223	.25094	.96800	.26780	.96347	.28457	.95865	28
33	.23429	.97217	.25122	.96793	.26808	.96340	.28485	.95857	27
34	.23458	.97210	.25151	.96786	.26836	.96332	.28513	.95849	26
35	.23486	.97203	.25179	.96778	.26864	.96324	.28541	.95841	25
36	.23514	.97196	.25207	.96771	.26892	.96316	.28569	.95832	24
37	.23542	.97189	.25235	.96764	.26920	.96308	.28597	.95824	23
38	.23571	.97182	.25263	.96756	.26948	.96301	.28625	.95816	22
39	.23599	.97176	.25291	.96749	.26976	.96293	.28652	.95807	21
40	.23627	.97169	.25320	.96742	.27004	.96285	.28680	.95799	20
41	.23656	.97162	.25348	.96734	.27032	.96277	.28708	.95791	19
42	.23684	.97155	.25376	.96727	.27060	.96269	.28736	.95782	18
43	.23712	.97148	.25404	.96719	.27088	.96261	.28764	.95774	17
44	.23740	.97141	.25432	.96712	.27116	.96253	.28792	.95766	16
45	.23769	.97134	.25460	.96705	.27144	.96246	.28820	.95757	15
46	.23797	.97127	.25488	.96697	.27172	.96238	.28847	.95749	14
47	.23825	.97120	.25516	.96690	.27200	.96230	.28875	.95740	13
48	.23853	.97113	.25545	.96682	.27228	.96222	.28903	.95732	12
49	.23882	.97106	.25573	.96675	.27256	.96214	.28931	.95724	11
50	.23910	.97100	.25601	.96667	.27284	.96206	.28959	.95715	10
51	.23938	.97093	.25629	.96660	.27312	.96198	.28987	.95707	9
52	.23966	.97086	.25657	.96653	.27340	.96190	.29015	.95698	8
53	.23995	.97079	.25685	.96645	.27368	.96182	.29042	.95690	7
54	.24023	.97072	.25713	.96638	.27396	.96174	.29070	.95681	6
55	.24051	.97065	.25741	.96630	.27424	.96166	.29098	.95673	5
56	.24079	.97058	.25769	.96623	.27452	.96158	.29126	.95664	4
57	.24108	.97051	.25798	.96615	.27480	.96150	.29154	.95656	3
58	.24136	.97044	.25826	.96608	.27508	.96142	.29182	.95647	2
59	.24164	.97037	.25854	.96600	.27536	.96134	.29209	.95639	1
60	.24192	.97030	.25882	.96593	.27564	.96126	.29237	.95630	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	76°		75°		74°		73°		

′	17° Sine	17° Cosine	18° Sine	18° Cosine	19° Sine	19° Cosine	20° Sine	20° Cosine	′
0	.29237	.95630	.30902	.95106	.32557	.94552	.34202	.93969	60
1	.29265	.95622	.30929	.95097	.32584	.94542	.34229	.93959	59
2	.29293	.95613	.30957	.95088	.32612	.94533	.34257	.93949	58
3	.29321	.95605	.30985	.95079	.32639	.94523	.34284	.93939	57
4	.29348	.95596	.31012	.95070	.32667	.94514	.34311	.93929	56
5	.29376	.95588	.31040	.95061	.32694	.94504	.34339	.93919	55
6	.29404	.95579	.31068	.95052	.32722	.94495	.34366	.93909	54
7	.29432	.95571	.31095	.95043	.32749	.94485	.34393	.93899	53
8	.29460	.95562	.31123	.95033	.32777	.94476	.34421	.93889	52
9	.29487	.95554	.31151	.95024	.32804	.94466	.34448	.93879	51
0	.29515	.95545	.31178	.95015	.32832	.94457	.34475	.93869	50
1	.29543	.95536	.31206	.95006	.32859	.94447	.34503	.93859	49
2	.29571	.95528	.31233	.94997	.32887	.94438	.34530	.93849	48
3	.29599	.95519	.31261	.94988	.32914	.94428	.34557	.93839	47
4	.29626	.95511	.31289	.94979	.32942	.94418	.34584	.93829	46
5	.29654	.95502	.31316	.94970	.32969	.94409	.34612	.93819	45
6	.29682	.95493	.31344	.94961	.32997	.94399	.34639	.93809	44
7	.29710	.95485	.31372	.94952	.33024	.94390	.34666	.93799	43
8	.29737	.95476	.31399	.94943	.33051	.94380	.34694	.93789	42
9	.29765	.95467	.31427	.94933	.33079	.94370	.34721	.93779	41
0	.29793	.95459	.31454	.94924	.33106	.94361	.34748	.93769	40
1	.29821	.95450	.31482	.94915	.33134	.94351	.34775	.93759	39
2	.29849	.95441	.31510	.94906	.33161	.94342	.34803	.93748	38
3	.29876	.95433	.31537	.94897	.33189	.94332	.34830	.93738	37
4	.29904	.95424	.31565	.94888	.33216	.94322	.34857	.93728	36
5	.29932	.95415	.31593	.94878	.33244	.94313	.34884	.93718	35
6	.29960	.95407	.31620	.94869	.33271	.94303	.34912	.93708	34
7	.29987	.95398	.31648	.94860	.33298	.94293	.34939	.93698	33
8	.30015	.95389	.31675	.94851	.33326	.94284	.34966	.93688	32
9	.30043	.95380	.31703	.94842	.33353	.94274	.34993	.93677	31
0	.30071	.95372	.31730	.94832	.33381	.94264	.35021	.93667	30
1	.30098	.95363	.31758	.94823	.33408	.94254	.35048	.93657	29
2	.30126	.95354	.31786	.94814	.33436	.94245	.35075	.93647	28
3	.30154	.95345	.31813	.94805	.33463	.94235	.35102	.93637	27
4	.30182	.95337	.31841	.94795	.33490	.94225	.35130	.93626	26
5	.30209	.95328	.31868	.94786	.33518	.94215	.35157	.93616	25
6	.30237	.95319	.31896	.94777	.33545	.94206	.35184	.93606	24
7	.30265	.95310	.31923	.94768	.33573	.94196	.35211	.93596	23
8	.30292	.95301	.31951	.94758	.33600	.94186	.35239	.93585	22
9	.30320	.95293	.31979	.94749	.33627	.94176	.35266	.93575	21
0	.30348	.95284	.32006	.94740	.33655	.94167	.35293	.93565	20
1	.30376	.95275	.32034	.94730	.33682	.94157	.35320	.93555	19
2	.30403	.95266	.32061	.94721	.33710	.94147	.35347	.93544	18
3	.30431	.95257	.32089	.94712	.33737	.94137	.35375	.93534	17
4	.30459	.95248	.32116	.94702	.33764	.94127	.35402	.93524	16
5	.30486	.95240	.32144	.94693	.33792	.94118	.35429	.93514	15
6	.30514	.95231	.32171	.94684	.33819	.94108	.35456	.93503	14
7	.30542	.95222	.32199	.94674	.33846	.94098	.35484	.93493	13
8	.30570	.95213	.32227	.94665	.33874	.94088	.35511	.93483	12
9	.30597	.95204	.32254	.94656	.33901	.94078	.35538	.93472	11
0	.30625	.95195	.32282	.94646	.33929	.94068	.35565	.93462	10
1	.30653	.95186	.32309	.94637	.33956	.94058	.35592	.93452	9
2	.30680	.95177	.32337	.94627	.33983	.94049	.35619	.93441	8
3	.30708	.95168	.32364	.94618	.34011	.94039	.35647	.93431	7
4	.30736	.95159	.32392	.94609	.34038	.94029	.35674	.93420	6
5	.30763	.95150	.32419	.94599	.34065	.94019	.35701	.93410	5
6	.30791	.95142	.32447	.94590	.34093	.94009	.35728	.93400	4
7	.30819	.95133	.32474	.94580	.34120	.93999	.35755	.93389	3
8	.30846	.95124	.32502	.94571	.34147	.93989	.35782	.93379	2
9	.30874	.95115	.32529	.94561	.34175	.93979	.35810	.93368	1
0	.30902	.95106	.32557	.94552	.34202	.93969	.35837	.93358	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	72°		71°		70°		69°		

′	21° Sine	21° Cosine	22° Sine	22° Cosine	23° Sine	23° Cosine	24° Sine	24° Cosine	′
0	.35837	.93358	.37461	.92718	.39073	.92050	.40674	.91355	60
1	.35864	.93348	.37488	.92707	.39100	.92039	.40700	.91343	59
2	.35891	.93337	.37515	.92697	.39127	.92028	.40727	.91331	58
3	.35918	.93327	.37542	.92686	.39153	.92016	.40753	.91319	57
4	.35945	.93316	.37569	.92675	.39180	.92005	.40780	.91307	56
5	.35973	.93306	.37595	.92664	.39207	.91994	.40806	.91295	55
6	.36000	.93295	.37622	.92653	.39234	.91982	.40833	.91283	54
7	.36027	.93285	.37649	.92642	.39260	.91971	.40860	.91272	53
8	.36054	.93274	.37676	.92631	.39287	.91959	.40886	.91260	52
9	.36081	.93264	.37703	.92620	.39314	.91948	.40913	.91248	51
10	.36108	.93253	.37730	.92609	.39341	.91936	.40939	.91236	50
11	.36135	.93243	.37757	.92598	.39367	.91925	.40966	.91224	49
12	.36162	.93232	.37784	.92587	.39394	.91914	.40992	.91212	48
13	.36190	.93222	.37811	.92576	.39421	.91902	.41019	.91200	47
14	.36217	.93211	.37838	.92565	.39448	.91891	.41045	.91188	46
15	.36244	.93201	.37865	.92554	.39474	.91879	.41072	.91176	45
16	.36271	.93190	.37892	.92543	.39501	.91868	.41098	.91164	44
17	.36298	.93180	.37919	.92532	.39528	.91856	.41125	.91152	43
18	.36325	.93169	.37946	.92521	.39555	.91845	.41151	.91140	42
19	.36352	.93159	.37973	.92510	.39581	.91833	.41178	.91128	41
20	.36379	.93148	.37999	.92499	.39608	.91822	.41204	.91116	40
21	.36406	.93137	.38026	.92488	.39635	.91810	.41231	.91104	39
22	.36434	.93127	.38053	.92477	.39661	.91799	.41257	.91092	38
23	.36461	.93116	.38080	.92466	.39688	.91787	.41284	.91080	37
24	.36488	.93106	.38107	.92455	.39715	.91775	.41310	.91068	36
25	.36515	.93095	.38134	.92444	.39741	.91764	.41337	.91056	35
26	.36542	.93084	.38161	.92432	.39768	.91752	.41363	.91044	34
27	.36569	.93074	.38188	.92421	.39795	.91741	.41390	.91032	33
28	.36596	.93063	.38215	.92410	.39822	.91729	.41416	.91020	32
29	.36623	.93052	.38241	.92399	.39848	.91718	.41443	.91008	31
30	.36650	.93042	.38268	.92388	.39875	.91706	.41469	.90996	30
31	.36677	.93031	.38295	.92377	.39902	.91694	.41496	.90984	29
32	.36704	.93020	.38322	.92366	.39928	.91683	.41522	.90972	28
33	.36731	.93010	.38349	.92355	.39955	.91671	.41549	.90960	27
34	.36758	.92999	.38376	.92343	.39982	.91660	.41575	.90948	26
35	.36785	.92988	.38403	.92332	.40008	.91648	.41602	.90936	25
36	.36812	.92978	.38430	.92321	.40035	.91636	.41628	.90924	24
37	.36839	.92967	.38456	.92310	.40062	.91625	.41655	.90911	23
38	.36867	.92956	.38483	.92299	.40088	.91613	.41681	.90899	22
39	.36894	.92945	.38510	.92287	.40115	.91601	.41707	.90887	21
40	.36921	.92935	.38537	.92276	.40141	.91590	.41734	.90875	20
41	.36948	.92924	.38564	.92265	.40168	.91578	.41760	.90863	19
42	.36975	.92913	.38591	.92254	.40195	.91566	.41787	.90851	18
43	.37002	.92902	.38617	.92243	.40221	.91555	.41813	.90839	17
44	.37029	.92892	.38644	.92231	.40248	.91543	.41840	.90826	16
45	.37056	.92881	.38671	.92220	.40275	.91531	.41866	.90814	15
46	.37083	.92870	.38698	.92209	.40301	.91519	.41892	.90802	14
47	.37110	.92859	.38725	.92198	.40328	.91508	.41919	.90790	13
48	.37137	.92849	.38752	.92186	.40355	.91496	.41945	.90778	12
49	.37164	.92838	.38778	.92175	.40381	.91484	.41972	.90766	11
50	.37191	.92827	.38805	.92164	.40408	.91472	.41998	.90753	10
51	.37218	.92816	.38832	.92152	.40434	.91461	.42024	.90741	9
52	.37245	.92805	.38859	.92141	.40461	.91449	.42051	.90729	8
53	.37272	.92794	.38886	.92130	.40488	.91437	.42077	.90717	7
54	.37299	.92784	.38912	.92119	.40514	.91425	.42104	.90704	6
55	.37326	.92773	.38939	.92107	.40541	.91414	.42130	.90692	5
56	.37353	.92762	.38966	.92096	.40567	.91402	.42156	.90680	4
57	.37380	.92751	.38993	.92085	.40594	.91390	.42183	.90668	3
58	.37407	.92740	.39020	.92073	.40620	.91378	.42209	.90655	2
59	.37434	.92729	.39046	.92062	.40647	.91366	.42235	.90643	1
60	.37461	.92718	.39073	.92050	.40674	.91355	.42262	.90631	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	68°		67°		66°		65°		

25°		26°		27°		28°		
Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	′
.42262	.90631	.43837	.89879	.45399	.89101	.46947	.88295	60
.42288	.90618	.43863	.89867	.45425	.89087	.46973	.88281	59
.42315	.90606	.43889	.89854	.45451	.89074	.46999	.88267	58
.42341	.90594	.43916	.89841	.45477	.89061	.47024	.88254	57
.42367	.90582	.43942	.89828	.45503	.89048	.47050	.88240	56
.42394	.90569	.43968	.89816	.45529	.89035	.47076	.88226	55
.42420	.90557	.43994	.89803	.45554	.89021	.47101	.88213	54
.42446	.90545	.44020	.89790	.45580	.89008	.47127	.88199	53
.42473	.90532	.44046	.89777	.45606	.88995	.47153	.88185	52
.42499	.90520	.44072	.89764	.45632	.88981	.47178	.88172	51
.42525	.90507	.44098	.89752	.45658	.88968	.47204	.88158	50
.42552	.90495	.44124	.89739	.45684	.88955	.47229	.88144	49
.42578	.90483	.44151	.89726	.45710	.88942	.47255	.88130	48
.42604	.90470	.44177	.89713	.45736	.88928	.47281	.88117	47
.42631	.90458	.44203	.89700	.45762	.88915	.47306	.88103	46
.42657	.90446	.44229	.89687	.45787	.88902	.47332	.88089	45
.42683	.90433	.44255	.89674	.45813	.88888	.47358	.88075	44
.42709	.90421	.44281	.89662	.45839	.88875	.47383	.88062	43
.42736	.90408	.44307	.89649	.45865	.88862	.47409	.88048	42
.42762	.90396	.44333	.89636	.45891	.88848	.47434	.88034	41
.42788	.90383	.44359	.89623	.45917	.88835	.47460	.88020	40
.42815	.90371	.44385	.89610	.45942	.88822	.47486	.88006	39
.42841	.90358	.44411	.89597	.45968	.88808	.47511	.87993	38
.42867	.90346	.44437	.89584	.45994	.88795	.47537	.87979	37
.42894	.90334	.44464	.89571	.46020	.88782	.47562	.87965	36
.42920	.90321	.44490	.89558	.46046	.88768	.47588	.87951	35
.42946	.90309	.44516	.89545	.46072	.88755	.47614	.87937	34
.42972	.90296	.44542	.89532	.46097	.88741	.47639	.87923	33
.42999	.90284	.44568	.89519	.46123	.88728	.47665	.87909	32
.43025	.90271	.44594	.89506	.46149	.88715	.47690	.87896	31
.43051	.90259	.44620	.89493	.46175	.88701	.47716	.87882	30
.43077	.90246	.44646	.89480	.46201	.88688	.47741	.87868	29
.43104	.90233	.44672	.89467	.46226	.88674	.47767	.87854	28
.43130	.90221	.44698	.89454	.46252	.88661	.47793	.87840	27
.43156	.90208	.44724	.89441	.46278	.88647	.47818	.87826	26
.43182	.90196	.44750	.89428	.46304	.88634	.47844	.87812	25
.43209	.90183	.44776	.89415	.46330	.88620	.47869	.87798	24
.43235	.90171	.44802	.89402	.46355	.88607	.47895	.87784	23
.43261	.90158	.44828	.89389	.46381	.88593	.47920	.87770	22
.43287	.90146	.44854	.89376	.46407	.88580	.47946	.87756	21
.43313	.90133	.44880	.89363	.46433	.88566	.47971	.87743	20
.43340	.90120	.44906	.89350	.46458	.88553	.47997	.87729	19
.43366	.90108	.44932	.89337	.46484	.88539	.48022	.87715	18
.43392	.90095	.44958	.89324	.46510	.88526	.48048	.87701	17
.43418	.90082	.44984	.89311	.46536	.88512	.48073	.87687	16
.43445	.90070	.45010	.89298	.46561	.88499	.48099	.87673	15
.43471	.90057	.45036	.89285	.46587	.88485	.48124	.87659	14
.43497	.90045	.45062	.89272	.46613	.88472	.48150	.87645	13
.43523	.90032	.45088	.89259	.46639	.88458	.48175	.87631	12
.43549	.90019	.45114	.89245	.46664	.88445	.48201	.87617	11
.43575	.90007	.45140	.89232	.46690	.88431	.48226	.87603	10
.43602	.89994	.45166	.89219	.46716	.88417	.48252	.87589	9
.43628	.89981	.45192	.89206	.46742	.88404	.48277	.87575	8
.43654	.89968	.45218	.89193	.46767	.88390	.48303	.87561	7
.43680	.89956	.45243	.89180	.46793	.88377	.48328	.87546	6
.43706	.89943	.45269	.89167	.46819	.88363	.48354	.87532	5
.43733	.89930	.45295	.89153	.46844	.88349	.48379	.87518	4
.43759	.89918	.45321	.89140	.46870	.88336	.48405	.87504	3
.43785	.89905	.45347	.89127	.46896	.88322	.48430	.87490	2
.43811	.89892	.45373	.89114	.46921	.88308	.48456	.87476	1
.43837	.89879	.45399	.89101	.46947	.88295	.48481	.87462	0
Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
64°		63°		62°		61°		

′	29° Sine	29° Cosine	30° Sine	30° Cosine	31° Sine	31° Cosine	32° Sine	32° Cosine	′
0	.48481	.87462	.50000	.86603	.51504	.85717	.52992	.84805	60
1	.48506	.87448	.50025	.86588	.51529	.85702	.53017	.84789	59
2	.48532	.87434	.50050	.86573	.51554	.85687	.53041	.84774	58
3	.48557	.87420	.50076	.86559	.51579	.85672	.53066	.84759	57
4	.48583	.87406	.50101	.86544	.51604	.85657	.53091	.84743	56
5	.48608	.87391	.50126	.86530	.51628	.85642	.53115	.84728	55
6	.48634	.87377	.50151	.86515	.51653	.85627	.53140	.84712	54
7	.48659	.87363	.50176	.86501	.51678	.85612	.53164	.84697	53
8	.48684	.87349	.50201	.86486	.51703	.85597	.53189	.84681	52
9	.48710	.87335	.50227	.86471	.51728	.85582	.53214	.84666	51
10	.48735	.87321	.50252	.86457	.51753	.85567	.53238	.84650	50
11	.48761	.87306	.50277	.86442	.51778	.85551	.53263	.84635	49
12	.48786	.87292	.50302	.86427	.51803	.85536	.53288	.84619	48
13	.48811	.87278	.50327	.86413	.51828	.85521	.53312	.84604	47
14	.48837	.87264	.50352	.86398	.51852	.85506	.53337	.84588	46
15	.48862	.87250	.50377	.86384	.51877	.85491	.53361	.84573	45
16	.48888	.87235	.50403	.86369	.51902	.85476	.53386	.84557	44
17	.48913	.87221	.50428	.86354	.51927	.85461	.53411	.84542	43
18	.48938	.87207	.50453	.86340	.51952	.85446	.53435	.84526	42
19	.48964	.87193	.50478	.86325	.51977	.85431	.53460	.84511	41
20	.48989	.87178	.50503	.86310	.52002	.85416	.53484	.84495	40
21	.49014	.87164	.50528	.86295	.52026	.85401	.53509	.84480	39
22	.49040	.87150	.50553	.86281	.52051	.85385	.53534	.84464	38
23	.49065	.87136	.50578	.86266	.52076	.85370	.53558	.84448	37
24	.49090	.87121	.50603	.86251	.52101	.85355	.53583	.84433	36
25	.49116	.87107	.50628	.86237	.52126	.85340	.53607	.84417	35
26	.49141	.87093	.50654	.86222	.52151	.85325	.53632	.84402	34
27	.49166	.87079	.50679	.86207	.52175	.85310	.53656	.84386	33
28	.49192	.87064	.50704	.86192	.52200	.85294	.53681	.84370	32
29	.49217	.87050	.50729	.86178	.52225	.85279	.53705	.84355	31
30	.49242	.87036	.50754	.86163	.52250	.85264	.53730	.84339	30
31	.49268	.87021	.50779	.86148	.52275	.85249	.53754	.84324	29
32	.49293	.87007	.50804	.86133	.52299	.85234	.53779	.84308	28
33	.49318	.86993	.50829	.86119	.52324	.85218	.53804	.84292	27
34	.49344	.86978	.50854	.86104	.52349	.85203	.53828	.84277	26
35	.49369	.86964	.50879	.86089	.52374	.85188	.53853	.84261	25
36	.49394	.86949	.50904	.86074	.52399	.85173	.53877	.84245	24
37	.49419	.86935	.50929	.86059	.52423	.85157	.53902	.84230	23
38	.49445	.86921	.50954	.86045	.52448	.85142	.53926	.84214	22
39	.49470	.86906	.50979	.86030	.52473	.85127	.53951	.84198	21
40	.49495	.86892	.51004	.86015	.52498	.85112	.53975	.84182	20
41	.49521	.86878	.51029	.86000	.52522	.85096	.54000	.84167	19
42	.49546	.86863	.51054	.85985	.52547	.85081	.54024	.84151	18
43	.49571	.86849	.51079	.85970	.52572	.85066	.54049	.84135	17
44	.49596	.86834	.51104	.85956	.52597	.85051	.54073	.84120	16
45	.49622	.86820	.51129	.85941	.52621	.85035	.54097	.84104	15
46	.49647	.86805	.51154	.85926	.52646	.85020	.54122	.84088	14
47	.49672	.86791	.51179	.85911	.52671	.85005	.54146	.84072	13
48	.49697	.86777	.51204	.85896	.52696	.84989	.54171	.84057	12
49	.49723	.86762	.51229	.85881	.52720	.84974	.54195	.84041	11
50	.49748	.86748	.51254	.85866	.52745	.84959	.54220	.84025	10
51	.49773	.86733	.51279	.85851	.52770	.84943	.54244	.84009	9
52	.49798	.86719	.51304	.85836	.52794	.84928	.54269	.83994	8
53	.49824	.86704	.51329	.85821	.52819	.84913	.54293	.83978	7
54	.49849	.86690	.51354	.85806	.52844	.84897	.54317	.83962	6
55	.49874	.86675	.51379	.85792	.52869	.84882	.54342	.83946	5
56	.49899	.86661	.51404	.85777	.52893	.84866	.54366	.83930	4
57	.49924	.86646	.51429	.85762	.52918	.84851	.54391	.83915	3
58	.49950	.86632	.51454	.85747	.52943	.84836	.54415	.83899	2
59	.49975	.86617	.51479	.85732	.52967	.84820	.54440	.83883	1
60	.50000	.86603	.51504	.85717	.52992	.84805	.54464	.83867	0
′	60° Cosine	60° Sine	59° Cosine	59° Sine	58° Cosine	58° Sine	57° Cosine	57° Sine	′

33°		34°		35°		36°		
Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	′
.54464	.83867	.55919	.82904	.57358	.81915	.58779	.80902	60
.54488	.83851	.55943	.82887	.57381	.81899	.58802	.80885	59
.54513	.83835	.55968	.82871	.57405	.81882	.58826	.80867	58
.54537	.83819	.55992	.82855	.57429	.81865	.58849	.80850	57
.54561	.83804	.56016	.82839	.57453	.81848	.58873	.80833	56
.54586	.83788	.56040	.82822	.57477	.81832	.58896	.80816	55
.54610	.83772	.56064	.82806	.57501	.81815	.58920	.80799	54
.54635	.83756	.56088	.82790	.57524	.81798	.58943	.80782	53
.54659	.83740	.56112	.82773	.57548	.81782	.58967	.80765	52
.54683	.83724	.56136	.82757	.57572	.81765	.58990	.80748	51
.54708	.83708	.56160	.82741	.57596	.81748	.59014	.80730	50
.54732	.83692	.56184	.82724	.57619	.81731	.59037	.80713	49
.54756	.83676	.56208	.82708	.57643	.81714	.59061	.80696	48
.54781	.83660	.56232	.82692	.57667	.81698	.59084	.80679	47
.54805	.83645	.56256	.82675	.57691	.81681	.59108	.80662	46
.54829	.83629	.56280	.82659	.57715	.81664	.59131	.80644	45
.54854	.83613	.56305	.82643	.57738	.81647	.59154	.80627	44
.54878	.83597	.56329	.82627	.57762	.81631	.59178	.80610	43
.54902	.83581	.56353	.82610	.57786	.81614	.59201	.80593	42
.54927	.83565	.56377	.82593	.57810	.81597	.59225	.80576	41
.54951	.83549	.56401	.82577	.57833	.81580	.59248	.80558	40
.54975	.83533	.56425	.82561	.57857	.81563	.59272	.80541	39
.54999	.83517	.56449	.82544	.57881	.81546	.59295	.80524	38
.55024	.83501	.56473	.82528	.57904	.81530	.59318	.80507	37
.55048	.83485	.56497	.82511	.57928	.81513	.59342	.80489	36
.55072	.83469	.56521	.82495	.57952	.81496	.59365	.80472	35
.55097	.83453	.56545	.82478	.57976	.81479	.59389	.80455	34
.55121	.83437	.56569	.82462	.57999	.81462	.59412	.80438	33
.55145	.83421	.56593	.82446	.58023	.81445	.59436	.80420	32
.55169	.83405	.56617	.82429	.58047	.81428	.59459	.80403	31
.55194	.83389	.56641	.82413	.58070	.81412	.59482	.80386	30
.55218	.83373	.56665	.82396	.58094	.81395	.59506	.80368	29
.55242	.83356	.56689	.82380	.58118	.81378	.59529	.80351	28
.55266	.83340	.56713	.82363	.58141	.81361	.59552	.80334	27
.55291	.83324	.56736	.82347	.58165	.81344	.59576	.80316	26
.55315	.83308	.56760	.82330	.58189	.81327	.59599	.80299	25
.55339	.83292	.56784	.82314	.58212	.81310	.59622	.80282	24
.55363	.83276	.56808	.82297	.58236	.81293	.59646	.80264	23
.55388	.83260	.56832	.82281	.58260	.81276	.59669	.80247	22
.55412	.83244	.56856	.82264	.58283	.81259	.59693	.80230	21
.55436	.83228	.56880	.82248	.58307	.81242	.59716	.80212	20
.55460	.83212	.56904	.82231	.58330	.81225	.59739	.80195	19
.55484	.83195	.56928	.82214	.58354	.81208	.59763	.80178	18
.55509	.83179	.56952	.82198	.58378	.81191	.59786	.80160	17
.55533	.83163	.56976	.82181	.58401	.81174	.59809	.80143	16
.55557	.83147	.57000	.82165	.58425	.81157	.59832	.80125	15
.55581	.83131	.57024	.82148	.58449	.81140	.59856	.80108	14
.55605	.83115	.57047	.82132	.58472	.81123	.59879	.80091	13
.55630	.83098	.57071	.82115	.58496	.81106	.59902	.80073	12
.55654	.83082	.57095	.82098	.58519	.81089	.59926	.80056	11
.55678	.83066	.57119	.82082	.58543	.81072	.59949	.80038	10
.55702	.83050	.57143	.82065	.58567	.81055	.59972	.80021	9
.55726	.83034	.57167	.82048	.58590	.81038	.59995	.80003	8
.55750	.83017	.57191	.82032	.58614	.81021	.60019	.79986	7
.55775	.83001	.57215	.82015	.58637	.81004	.60042	.79968	6
.55799	.82985	.57238	.81999	.58661	.80987	.60065	.79951	5
.55823	.82969	.57262	.81982	.58684	.80970	.60089	.79934	4
.55847	.82953	.57286	.81965	.58708	.80953	.60112	.79916	3
.55871	.82936	.57310	.81949	.58731	.80936	.60135	.79899	2
.55895	.82920	.57334	.81932	.58755	.80919	.60158	.79881	1
.55919	.82904	.57358	.81915	.58779	.80902	.60182	.79864	0
Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
56°		55°		54°		53°		

′	37°		38°		39°		40°		′
	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	
0	.60182	.79864	.61566	.78801	.62932	.77715	.64279	.76604	60
1	.60205	.79846	.61589	.78783	.62955	.77696	.64301	.76586	59
2	.60228	.79829	.61612	.78765	.62977	.77678	.64323	.76567	58
3	.60251	.79811	.61635	.78747	.63000	.77660	.64346	.76548	57
4	.60274	.79793	.61658	.78729	.63022	.77641	.64368	.76530	56
5	.60298	.79776	.61681	.78711	.63045	.77623	.64390	.76511	55
6	.60321	.79758	.61704	.78694	.63068	.77605	.64412	.76492	54
7	.60344	.79741	.61726	.78676	.63090	.77586	.64435	.76473	53
8	.60367	.79723	.61749	.78658	.63113	.77568	.64457	.76455	52
9	.60390	.79706	.61772	.78640	.63135	.77550	.64479	.76436	51
10	.60414	.79688	.61795	.78622	.63158	.77531	.64501	.76417	50
11	.60437	.79671	.61818	.78604	.63180	.77513	.64524	.76398	49
12	.60460	.79653	.61841	.78586	.63203	.77494	.64546	.76380	48
13	.60483	.79635	.61864	.78568	.63225	.77476	.64568	.76361	47
14	.60506	.79618	.61887	.78550	.63248	.77458	.64590	.76342	46
15	.60529	.79600	.61909	.78532	.63271	.77439	.64612	.76323	45
16	.60553	.79583	.61932	.78514	.63293	.77421	.64635	.76304	44
17	.60576	.79565	.61955	.78496	.63316	.77402	.64657	.76286	43
18	.60599	.79547	.61978	.78478	.63338	.77384	.64679	.76267	42
19	.60622	.79530	.62001	.78460	.63361	.77366	.64701	.76248	41
20	.60645	.79512	.62024	.78442	.63383	.77347	.64723	.76229	40
21	.60668	.79494	.62046	.78424	.63406	.77329	.64746	.76210	39
22	.60691	.79477	.62069	.78405	.63428	.77310	.64768	.76192	38
23	.60714	.79459	.62092	.78387	.63451	.77292	.64790	.76173	37
24	.60738	.79441	.62115	.78369	.63473	.77273	.64812	.76154	36
25	.60761	.79424	.62138	.78351	.63496	.77255	.64834	.76135	35
26	.60784	.79406	.62160	.78333	.63518	.77236	.64856	.76116	34
27	.60807	.79388	.62183	.78315	.63540	.77218	.64878	.76097	33
28	.60830	.79371	.62206	.78297	.63563	.77199	.64901	.76078	32
29	.60853	.79353	.62229	.78279	.63585	.77181	.64923	.76059	31
30	.60876	.79335	.62251	.78261	.63608	.77162	.64945	.76041	30
31	.60899	.79318	.62274	.78243	.63630	.77144	.64967	.76022	29
32	.60922	.79300	.62297	.78225	.63653	.77125	.64989	.76003	28
33	.60945	.79282	.62320	.78206	.63675	.77107	.65011	.75984	27
34	.60968	.79264	.62342	.78188	.63698	.77088	.65033	.75965	26
35	.60991	.79247	.62365	.78170	.63720	.77070	.65055	.75946	25
36	.61015	.79229	.62388	.78152	.63742	.77051	.65077	.75927	24
37	.61038	.79211	.62411	.78134	.63765	.77033	.65100	.75908	23
38	.61061	.79193	.62433	.78116	.63787	.77014	.65122	.75889	22
39	.61084	.79176	.62456	.78098	.63810	.76996	.65144	.75870	21
40	.61107	.79158	.62479	.78079	.63832	.76977	.65166	.75851	20
41	.61130	.79140	.62502	.78061	.63854	.76959	.65188	.75832	19
42	.61153	.79122	.62524	.78043	.63877	.76940	.65210	.75813	18
43	.61176	.79105	.62547	.78025	.63899	.76921	.65232	.75794	17
44	.61199	.79087	.62570	.78007	.63922	.76903	.65254	.75775	16
45	.61222	.79069	.62592	.77988	.63944	.76884	.65276	.75756	15
46	.61245	.79051	.62615	.77970	.63966	.76866	.65298	.75738	14
47	.61268	.79033	.62638	.77952	.63989	.76847	.65320	.75719	13
48	.61291	.79016	.62660	.77934	.64011	.76828	.65342	.75700	12
49	.61314	.78998	.62683	.77916	.64033	.76810	.65364	.75680	11
50	.61337	.78980	.62706	.77897	.64056	.76791	.65386	.75661	10
51	.61360	.78962	.62728	.77879	.64078	.76772	.65408	.75642	9
52	.61383	.78944	.62751	.77861	.64100	.76754	.65430	.75623	8
53	.61406	.78926	.62774	.77843	.64123	.76735	.65452	.75604	7
54	.61429	.78908	.62796	.77824	.64145	.76717	.65474	.75585	6
55	.61451	.78891	.62819	.77806	.64167	.76698	.65496	.75566	5
56	.61474	.78873	.62842	.77788	.64190	.76679	.65518	.75547	4
57	.61497	.78855	.62864	.77769	.64212	.76661	.65540	.75528	3
58	.61520	.78837	.62887	.77751	.64234	.76642	.65562	.75509	2
59	.61543	.78819	.62909	.77733	.64256	.76623	.65584	.75490	1
60	.61566	.78801	.62932	.77715	.64279	.76604	.65606	.75471	0
′	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
	52°		51°		50°		49°		

41°		42°		43°		44°		
Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	′
.65606	.75471	.66913	.74314	.68200	.73135	.69466	.71934	60
.65628	.75452	.66935	.74295	.68221	.73116	.69487	.71914	59
.65650	.75433	.66956	.74276	.68242	.73096	.69508	.71894	58
.65672	.75414	.66978	.74256	.68264	.73076	.69529	.71873	57
.65694	.75395	.66999	.74237	.68285	.73056	.69549	.71853	56
.65716	.75375	.67021	.74217	.68306	.73036	.69570	.71833	55
.65738	.75356	.67043	.74198	.68327	.73016	.69591	.71813	54
.65759	.75337	.67064	.74178	.68349	.72996	.69612	.71792	53
.65781	.75318	.67086	.74159	.68370	.72976	.69633	.71772	52
.65803	.75299	.67107	.74139	.68391	.72957	.69654	.71752	51
.65825	.75280	.67129	.74120	.68412	.72937	.69675	.71732	50
.65847	.75261	.67151	.74100	.68434	.72917	.69696	.71711	49
.65869	.75241	.67172	.74080	.68455	.72897	.69717	.71691	48
.65891	.75222	.67194	.74061	.68476	.72877	.69737	.71671	47
.65913	.75203	.67215	.74041	.68497	.72857	.69758	.71650	46
.65935	.75184	.67237	.74022	.68518	.72837	.69779	.71630	45
.65956	.75165	.67258	.74002	.68539	.72817	.69800	.71610	44
.65978	.75146	.67280	.73983	.68561	.72797	.69821	.71590	43
.66000	.75126	.67301	.73963	.68582	.72777	.69842	.71569	42
.66022	.75107	.67323	.73944	.68603	.72757	.69862	.71549	41
.66044	.75088	.67344	.73924	.68624	.72737	.69883	.71529	40
.66066	.75069	.67366	.73904	.68645	.72717	.69904	.71508	39
.66088	.75050	.67387	.73885	.68666	.72697	.69925	.71488	38
.66109	.75030	.67409	.73865	.68688	.72677	.69946	.71468	37
.66131	.75011	.67430	.73846	.68709	.72657	.69966	.71447	36
.66153	.74992	.67452	.73826	.68730	.72637	.69987	.71427	35
.66175	.74973	.67473	.73806	.68751	.72617	.70008	.71407	34
.66197	.74953	.67495	.73787	.68772	.72597	.70029	.71386	33
.66218	.74934	.67516	.73767	.68793	.72577	.70049	.71366	32
.66240	.74915	.67538	.73747	.68814	.72557	.70070	.71345	31
.66262	.74896	.67559	.73728	.68835	.72537	.70091	.71325	30
.66284	.74876	.67580	.73708	.68857	.72517	.70112	.71305	29
.66306	.74857	.67602	.73688	.68878	.72497	.70132	.71284	28
.66327	.74838	.67623	.73669	.68899	.72477	.70153	.71264	27
.66349	.74818	.67645	.73649	.68920	.72457	.70174	.71243	26
.66371	.74799	.67666	.73629	.68941	.72437	.70195	.71223	25
.66393	.74780	.67688	.73610	.68962	.72417	.70215	.71203	24
.66414	.74760	.67709	.73590	.68983	.72397	.70236	.71182	23
.66436	.74741	.67730	.73570	.69004	.72377	.70257	.71162	22
.66458	.74722	.67752	.73551	.69025	.72357	.70277	.71141	21
.66480	.74703	.67773	.73531	.69046	.72337	.70298	.71121	20
.66501	.74683	.67795	.73511	.69067	.72317	.70319	.71100	19
.66523	.74664	.67816	.73491	.69088	.72297	.70339	.71080	18
.66545	.74644	.67837	.73472	.69109	.72277	.70360	.71059	17
.66566	.74625	.67859	.73452	.69130	.72257	.70381	.71039	16
.66588	.74606	.67880	.73432	.69151	.72236	.70401	.71019	15
.66610	.74586	.67901	.73413	.69172	.72216	.70422	.70998	14
.66632	.74567	.67923	.73393	.69193	.72196	.70443	.70978	13
.66653	.74548	.67944	.73373	.69214	.72176	.70463	.70957	12
.66675	.74528	.67965	.73353	.69235	.72156	.70484	.70937	11
.66697	.74509	.67987	.73333	.69256	.72136	.70505	.70916	10
.66718	.74489	.68008	.73314	.69277	.72116	.70525	.70896	9
.66740	.74470	.68029	.73294	.69298	.72095	.70546	.70875	8
.66762	.74451	.68051	.73274	.69319	.72075	.70567	.70855	7
.66783	.74431	.68072	.73254	.69340	.72055	.70587	.70834	6
.66805	.74412	.68093	.73234	.69361	.72035	.70608	.70813	5
.66827	.74392	.68115	.73215	.69382	.72015	.70628	.70793	4
.66848	.74373	.68136	.73195	.69403	.71995	.70649	.70772	3
.66870	.74353	.68157	.73175	.69424	.71974	.70670	.70752	2
.66891	.74334	.68179	.73155	.69445	.71954	.70690	.70731	1
.66913	.74314	.68200	.73135	.69466	.71934	.70711	.70711	0
Cosine	Sine	Cosine	Sine	Cosine	Sine	Cosine	Sine	′
48°		47°		46°		45°		

′	0° Sec.	0° Co-sec.	1° Sec.	1° Co-sec.	2° Sec.	2° Co-sec.	Sec.
0	1	Infinite.	1.0002	57.299	1.0006	28.654	1.001
1	1	3437.70	1.0002	56.350	1.0006	28.417	1.001
2	1	1718.90	1.0002	55.450	1.0006	28.184	1.001
3	1	1145.90	1.0002	54.570	1.0006	27.955	1.001
4	1	859.44	1.0002	53.718	1.0006	27.730	1.001
5	1	687.55	1.0002	52.891	1.0007	27.508	1.001
6	1	572.96	1.0002	52.090	1.0007	27.290	1.001
7	1	491.11	1.0002	51.313	1.0007	27.075	1.001
8	1	429.72	1.0002	50.558	1.0007	26.864	1.001
9	1	381.97	1.0002	49.826	1.0007	26.655	1.001
10	1	343.77	1.0002	49.114	1.0007	26.450	1.001
11	1	312.52	1.0002	48.422	1.0007	26.249	1.001
12	1	286.48	1.0002	47.750	1.0007	26.050	1.001
13	1	264.44	1.0002	47.096	1.0007	25.854	1.001
14	1	245.55	1.0002	46.460	1.0008	25.661	1.001
15	1	229.18	1.0002	45.840	1.0008	25.471	1.001
16	1	214.86	1.0002	45.237	1.0008	25.284	1.001
17	1	202.22	1.0002	44.650	1.0008	25.100	1.001
18	1	190.99	1.0002	44.077	1.0008	24.918	1.001
19	1	180.73	1.0003	43.520	1.0008	24.739	1.001
20	1	171.89	1.0003	42.976	1.0008	24.562	1.001
21	1	163.70	1.0003	42.445	1.0008	24.388	1.001
22	1	156.26	1.0003	41.928	1.0008	24.216	1.001
23	1	149.47	1.0003	41.423	1.0009	24.047	1.001
24	1	143.24	1.0003	40.930	1.0009	23.880	1.001
25	1	137.51	1.0003	40.448	1.0009	23.716	1.001
26	1	132.22	1.0003	39.978	1.0009	23.553	1.001
27	1	127.32	1.0003	39.518	1.0009	23.393	1.001
28	1	122.78	1.0003	39.069	1.0009	23.235	1.001
29	1	118.54	1.0003	38.631	1.0009	23.079	1.001
30	1	114.59	1.0003	38.201	1.0009	22.925	1.001
31	1	110.90	1.0003	37.782	1.0010	22.774	1.001
32	1	107.43	1.0003	37.371	1.0010	22.624	1.001
33	1	104.17	1.0004	36.969	1.0010	22.476	1.001
34	1	101.11	1.0004	36.576	1.0010	22.330	1.001
35	1	98.223	1.0004	36.191	1.0010	22.186	1.001
36	1	95.495	1.0004	35.814	1.0010	22.044	1.001
37	1	92.914	1.0004	35.445	1.0010	21.904	1.001
38	1.0001	90.469	1.0004	35.084	1.0010	21.765	1.001
39	1.0001	88.149	1.0004	34.729	1.0011	21.629	1.001
40	1.0001	85.946	1.0004	34.382	1.0011	21.494	1.001
41	1.0001	83.849	1.0004	34.042	1.0011	21.360	1.001
42	1.0001	81.853	1.0004	33.708	1.0011	21.228	1.001
43	1.0001	79.950	1.0004	33.381	1.0011	21.098	1.001
44	1.0001	78.133	1.0004	33.060	1.0011	20.970	1.001
45	1.0001	76.396	1.0005	32.745	1.0011	20.843	1.001
46	1.0001	74.736	1.0005	32.437	1.0012	20.717	1.001
47	1.0001	73.146	1.0005	32.134	1.0012	20.593	1.001
48	1.0001	71.622	1.0005	31.836	1.0012	20.471	1.001
49	1.0001	70.160	1.0005	31.544	1.0012	20.350	1.001
50	1.0001	68.757	1.0005	31.257	1.0012	20.230	1.001
51	1.0001	67.409	1.0005	30.976	1.0012	20.112	1.001
52	1.0001	66.113	1.0005	30.699	1.0012	19.995	1.001
53	1.0001	64.866	1.0005	30.428	1.0013	19.880	1.001
54	1.0001	63.664	1.0005	30.161	1.0013	19.766	1.001
55	1.0001	62.507	1.0005	29.899	1.0013	19.653	1.001
56	1.0001	61.391	1.0006	29.641	1.0013	19.541	1.001
57	1.0001	60.314	1.0006	29.388	1.0013	19.431	1.001
58	1.0001	59.274	1.0006	29.139	1.0013	19.322	1.001
59	1.0001	58.270	1.0006	28.894	1.0013	19.214	1.001
60	1.0001	57.299	1.0006	28.654	1.0014	19.107	1.001
′	89° Co-sec.	89° Sec.	88° Co-sec.	88° Sec.	87° Co-sec.	87° Sec.	Co-s

′	4°		5°		6°		7°		′
	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	
0	1.0024	14.335	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	60
1	1.0025	14.276	1.0038	11.436	1.0055	9.5404	1.0075	8.1861	59
2	1.0025	14.217	1.0039	11.398	1.0056	9.5141	1.0076	8.1668	58
3	1.0025	14.159	1.0039	11.360	1.0056	9.4880	1.0076	8.1476	57
4	1.0025	14.101	1.0039	11.323	1.0056	9.4620	1.0076	8.1285	56
5	1.0025	14.043	1.0039	11.286	1.0057	9.4362	1.0077	8.1094	55
6	1.0026	13.986	1.0040	11.249	1.0057	9.4105	1.0077	8.0905	54
7	1.0026	13.930	1.0040	11.213	1.0057	9.3850	1.0078	8.0717	53
8	1.0026	13.874	1.0040	11.176	1.0057	9.3596	1.0078	8.0529	52
9	1.0026	13.818	1.0040	11.140	1.0058	9.3343	1.0078	8.0342	51
10	1.0026	13.763	1.0041	11.104	1.0058	9.3092	1.0079	8.0156	50
11	1.0027	13.708	1.0041	11.069	1.0058	9.2842	1.0079	7.9971	49
12	1.0027	13.654	1.0041	11.033	1.0059	9.2593	1.0079	7.9787	48
13	1.0027	13.600	1.0041	10.998	1.0059	9.2346	1.0080	7.9604	47
14	1.0027	13.547	1.0042	10.963	1.0059	9.2100	1.0080	7.9421	46
15	1.0027	13.494	1.0042	10.929	1.0060	9.1855	1.0080	7.9240	45
16	1.0028	13.441	1.0042	10.894	1.0060	9.1612	1.0081	7.9059	44
17	1.0028	13.389	1.0043	10.860	1.0060	9.1370	1.0081	7.8879	43
18	1.0028	13.337	1.0043	10.826	1.0061	9.1129	1.0082	7.8700	42
19	1.0028	13.286	1.0043	10.792	1.0061	9.0890	1.0082	7.8522	41
20	1.0029	13.235	1.0043	10.758	1.0061	9.0651	1.0082	7.8344	40
21	1.0029	13.184	1.0044	10.725	1.0062	9.0414	1.0083	7.8168	39
22	1.0029	13.134	1.0044	10.692	1.0062	9.0179	1.0083	7.7992	38
23	1.0029	13.084	1.0044	10.659	1.0062	8.9944	1.0084	7.7817	37
24	1.0029	13.034	1.0044	10.626	1.0063	8.9711	1.0084	7.7642	36
25	1.0030	12.985	1.0045	10.593	1.0063	8.9479	1.0084	7.7469	35
26	1.0030	12.937	1.0045	10.561	1.0063	8.9248	1.0085	7.7296	34
27	1.0030	12.888	1.0045	10.529	1.0064	8.9018	1.0085	7.7124	33
28	1.0030	12.840	1.0046	10.497	1.0064	8.8790	1.0085	7.6953	32
29	1.0031	12.793	1.0046	10.465	1.0064	8.8563	1.0086	7.6783	31
30	1.0031	12.745	1.0046	10.433	1.0065	8.8337	1.0086	7.6613	30
31	1.0031	12.698	1.0046	10.402	1.0065	8.8112	1.0087	7.6444	29
32	1.0031	12.652	1.0047	10.371	1.0065	8.7888	1.0087	7.6276	28
33	1.0032	12.606	1.0047	10.340	1.0066	8.7665	1.0087	7.6108	27
34	1.0032	12.560	1.0047	10.309	1.0066	8.7444	1.0088	7.5942	26
35	1.0032	12.514	1.0048	10.278	1.0066	8.7223	1.0088	7.5776	25
36	1.0032	12.469	1.0048	10.248	1.0067	8.7004	1.0089	7.5612	24
37	1.0032	12.424	1.0048	10.217	1.0067	8.6786	1.0089	7.5446	23
38	1.0033	12.379	1.0048	10.187	1.0067	8.6569	1.0089	7.5282	22
39	1.0033	12.335	1.0049	10.157	1.0068	8.6353	1.0090	7.5119	21
40	1.0033	12.291	1.0049	10.127	1.0068	8.6138	1.0090	7.4957	20
41	1.0033	12.248	1.0049	10.098	1.0068	8.5924	1.0090	7.4795	19
42	1.0034	12.204	1.0050	10.068	1.0069	8.5711	1.0091	7.4634	18
43	1.0034	12.161	1.0050	10.039	1.0069	8.5499	1.0091	7.4474	17
44	1.0034	12.118	1.0050	10.010	1.0069	8.5289	1.0092	7.4315	16
45	1.0034	12.076	1.0050	9.9812	1.0070	8.5079	1.0092	7.4156	15
46	1.0035	12.034	1.0051	9.9525	1.0070	8.4871	1.0092	7.3998	14
47	1.0035	11.992	1.0051	9.9239	1.0070	8.4663	1.0093	7.3840	13
48	1.0035	11.950	1.0051	9.8955	1.0071	8.4457	1.0093	7.3683	12
49	1.0035	11.909	1.0052	9.8672	1.0071	8.4251	1.0094	7.3527	11
50	1.0036	11.868	1.0052	9.8391	1.0071	8.4046	1.0094	7.3372	10
51	1.0036	11.828	1.0052	9.8112	1.0072	8.3843	1.0094	7.3217	9
52	1.0036	11.787	1.0053	9.7834	1.0072	8.3640	1.0095	7.3063	8
53	1.0036	11.747	1.0053	9.7558	1.0073	8.3439	1.0095	7.2909	7
54	1.0037	11.707	1.0053	9.7283	1.0073	8.3238	1.0096	7.2757	6
55	1.0037	11.668	1.0053	9.7010	1.0073	8.3039	1.0096	7.2604	5
56	1.0037	11.628	1.0054	9.6739	1.0074	8.2840	1.0097	7.2453	4
57	1.0037	11.589	1.0054	9.6469	1.0074	8.2642	1.0097	7.2302	3
58	1.0038	11.550	1.0054	9.6200	1.0074	8.2446	1.0097	7.2152	2
59	1.0038	11.512	1.0055	9.5933	1.0075	8.2250	1.0098	7.2002	1
60	1.0038	11.474	1.0055	9.5668	1.0075	8.2055	1.0098	7.1853	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	85°		84°		83°		82°		

′	8° Sec.	8° Co-sec.	9° Sec.	9° Co-sec.	10° Sec.	10° Co.sec.	11° Sec.	11° Co-s
0	1.0098	7.1853	1.0125	6.3924	1.0154	5.7588	1.0187	5.24
1	1.0099	7.1704	1.0125	6.3807	1.0155	5.7493	1.0188	5.23
2	1.0099	7.1557	1.0125	6.3690	1.0155	5.7398	1.0188	5.22
3	1.0099	7.1409	1.0126	6.3574	1.0156	5.7304	1.0189	5.21
4	1.0100	7.1263	1.0126	6.3458	1.0156	5.7210	1.0189	5.20
5	1.0100	7.1117	1.0127	6.3343	1.0157	5.7117	1.0190	5.20
6	1.0101	7.0972	1.0127	6.3228	1.0157	5.7023	1.0191	5.19
7	1.0101	7.0827	1.0128	6.3113	1.0158	5.6930	1.0191	5.18
8	1.0102	7.0683	1.0128	6.2999	1.0158	5.6838	1.0192	5.17
9	1.0102	7.0539	1.0129	6.2885	1.0159	5.6745	1.0192	5.17
10	1.0102	7.0396	1.0129	6.2772	1.0159	5.6653	1.0193	5.16
11	1.0103	7.0254	1.0130	6.2659	1.0160	5.6561	1.0193	5.15
12	1.0103	7.0112	1.0130	6.2546	1.0160	5.6470	1.0194	5.14
13	1.0104	6.9971	1.0131	6.2434	1.0161	5.6379	1.0195	5.14
14	1.0104	6.9830	1.0131	6.2322	1.0162	5.6288	1.0195	5.13
15	1.0104	6.9690	1.0132	6.2211	1.0162	5.6197	1.0196	5.12
16	1.0105	6.9550	1.0132	6.2100	1.0163	5.6107	1.0196	5.11
17	1.0105	6.9411	1.0133	6.1990	1.0163	5.6017	1.0197	5.11
18	1.0106	6.9273	1.0133	6.1880	1.0164	5.5928	1.0198	5.10
19	1.0106	6.9135	1.0134	6.1770	1.0164	5.5838	1.0198	5.09
20	1.0107	6.8998	1.0134	6.1661	1.0165	5.5749	1.0199	5.08
21	1.0107	6.8861	1.0135	6.1552	1.0165	5.5660	1.0199	5.08
22	1.0107	6.8725	1.0135	6.1443	1.0166	5.5572	1.0200	5.07
23	1.0108	6.8589	1.0136	6.1335	1.0166	5.5484	1.0201	5.06
24	1.0108	6.8454	1.0136	6.1227	1.0167	5.5396	1.0201	5.05
25	1.0109	6.8320	1.0136	6.1120	1.0167	5.5308	1.0202	5.05
26	1.0109	6.8185	1.0137	6.1013	1.0168	5.5221	1.0202	5.04
27	1.0110	6.8052	1.0137	6.0906	1.0169	5.5134	1.0203	5.037
28	1.0110	6.7919	1.0138	6.0800	1.0169	5.5047	1.0204	5.030
29	1.0111	6.7787	1.0138	6.0694	1.0170	5.4960	1.0204	5.023
30	1.0111	6.7655	1.0139	6.0588	1.0170	5.4874	1.0205	5.015
31	1.0111	6.7523	1.0139	6.0483	1.0171	5.4788	1.0205	5.008
32	1.0112	6.7392	1.0140	6.0379	1.0171	5.4702	1.0206	5.001
33	1.0112	6.7262	1.0140	6.0274	1.0172	5.4617	1.0207	4.994
34	1.0113	6.7132	1.0141	6.0170	1.0172	5.4532	1.0207	4.987
35	1.0113	6.7003	1.0141	6.0066	1.0173	5.4447	1.0208	4.980
36	1.0114	6.6874	1.0142	5.9963	1.0174	5.4362	1.0208	4.973
37	1.0114	6.6745	1.0142	5.9860	1.0174	5.4278	1.0209	4.966
38	1.0115	6.6617	1.0143	5.9758	1.0175	5.4194	1.0210	4.959
39	1.0115	6.6490	1.0143	5.9655	1.0175	5.4110	1.0210	4.952
40	1.0115	6.6363	1.0144	5.9554	1.0176	5.4026	1.0211	4.945
41	1.0116	6.6237	1.0144	5.9452	1.0176	5.3943	1.0211	4.938
42	1.0116	6.6111	1.0145	5.9351	1.0177	5.3860	1.0212	4.931
43	1.0117	6.5985	1.0145	5.9250	1.0177	5.3777	1.0213	4.924
44	1.0117	6.5860	1.0146	5.9150	1.0178	5.3695	1.0213	4.917
45	1.0118	6.5736	1.0146	5.9049	1.0179	5.3612	1.0214	4.910
46	1.0118	6.5612	1.0147	5.8950	1.0179	5.3530	1.0215	4.903
47	1.0119	6.5488	1.0147	5.8850	1.0180	5.3449	1.0215	4.896
48	1.0119	6.5365	1.0148	5.8751	1.0180	5.3367	1.0216	4.890
49	1.0119	6.5243	1.0148	5.8652	1.0181	5.3286	1.0216	4.883
50	1.0120	6.5121	1.0149	5.8554	1.0181	5.3205	1.0217	4.876
51	1.0120	6.4999	1.0150	5.8456	1.0182	5.3124	1.0218	4.869
52	1.0121	6.4878	1.0150	5.8358	1.0182	5.3044	1.0218	4.863
53	1.0121	6.4757	1.0151	5.8261	1.0183	5.2963	1.0219	4.856
54	1.0122	6.4637	1.0151	5.8163	1.0184	5.2883	1.0220	4.849
55	1.0122	6.4517	1.0152	5.8067	1.0184	5.2803	1.0220	4.842
56	1.0123	6.4398	1.0152	5.7970	1.0185	5.2724	1.0221	4.836
57	1.0123	6.4279	1.0153	5.7874	1.0185	5.2645	1.0221	4.829
58	1.0124	6.4160	1.0153	5.7778	1.0186	5.2566	1.0222	4.822
59	1.0124	6.4042	1.0154	5.7683	1.0186	5.2487	1.0223	4.816
60	1.0125	6.3924	1.0154	5.7588	1.0187	5.2408	1.0223	4.809
′	Co-sec 81°	Sec. 81°	Co-sec 80°	Sec. 80°	Co-sec 79°	Sec. 79°	Co-sec. 78°	Sec. 78°

12°		13°		14°		15°		
Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	′
1.0223	4.8097	1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	60
1.0224	4.8032	1.0264	4.4398	1.0307	4.1287	1.0353	3.8595	59
1.0225	4.7966	1.0264	4.4342	1.0308	4.1239	1.0354	3.8553	58
1.0225	4.7901	1.0265	4.4287	1.0308	4.1191	1.0355	3.8512	57
1.0226	4.7835	1.0266	4.4231	1.0309	4.1144	1.0356	3.8470	56
1.0226	4.7770	1.0266	4.4176	1.0310	4.1096	1.0357	3.8428	55
1.0227	4.7706	1.0267	4.4121	1.0311	4.1048	1.0358	3.8387	54
1.0228	4.7641	1.0268	4.4065	1.0311	4.1001	1.0358	3.8346	53
1.0228	4.7576	1.0268	4.4011	1.0312	4.0953	1.0359	3.8304	52
1.0229	4.7512	1.0269	4.3956	1.0313	4.0906	1.0360	3.8263	51
1.0230	4.7448	1.0270	4.3901	1.0314	4.0859	1.0361	3.8222	50
1.0230	4.7384	1.0271	4.3847	1.0314	4.0812	1.0362	3.8181	49
1.0231	4.7320	1.0271	4.3792	1.0315	4.0765	1.0362	3.8140	48
1.0232	4.7257	1.0272	4.3738	1.0316	4.0718	1.0363	3.8100	47
1.0232	4.7193	1.0273	4.3684	1.0317	4.0672	1.0364	3.8059	46
1.0233	4.7130	1.0273	4.3630	1.0317	4.0625	1.0365	3.8018	45
1.0234	4.7067	1.0274	4.3576	1.0318	4.0579	1.0366	3.7978	44
1.0234	4.7004	1.0275	4.3522	1.0319	4.0532	1.0367	3.7937	43
1.0235	4.6942	1.0276	4.3469	1.0320	4.0486	1.0367	3.7897	42
1.0235	4.6879	1.0276	4.3415	1.0320	4.0440	1.0368	3.7857	41
1.0236	4.6817	1.0277	4.3362	1.0321	4.0394	1.0369	3.7816	40
1.0237	4.6754	1.0278	4.3309	1.0322	4.0348	1.0370	3.7776	39
1.0237	4.6692	1.0278	4.3256	1.0323	4.0302	1.0371	3.7736	38
1.0238	4.6631	1.0279	4.3203	1.0323	4.0256	1.0371	3.7697	37
1.0239	4.6569	1.0280	4.3150	1.0324	4.0211	1.0372	3.7657	36
1.0239	4.6507	1.0280	4.3098	1.0325	4.0165	1.0373	3.7617	35
1.0240	4.6446	1.0281	4.3045	1.0326	4.0120	1.0374	3.7577	34
1.0241	4.6385	1.0282	4.2993	1.0327	4.0074	1.0375	3.7538	33
1.0241	4.6324	1.0283	4.2941	1.0327	4.0029	1.0376	3.7498	32
1.0242	4.6263	1.0283	4.2888	1.0328	3.9984	1.0376	3.7459	31
1.0243	4.6202	1.0284	4.2836	1.0329	3.9939	1.0377	3.7420	30
1.0243	4.6142	1.0285	4.2785	1.0330	3.9894	1.0378	3.7380	29
1.0244	4.6081	1.0285	4.2733	1.0330	3.9850	1.0379	3.7341	28
1.0245	4.6021	1.0286	4.2681	1.0331	3.9805	1.0380	3.7302	27
1.0245	4.5961	1.0287	4.2630	1.0332	3.9760	1.0381	3.7263	26
1.0246	4.5901	1.0288	4.2579	1.0333	3.9716	1.0382	3.7224	25
1.0247	4.5841	1.0288	4.2527	1.0334	3.9672	1.0382	3.7186	24
1.0247	4.5782	1.0289	4.2476	1.0334	3.9627	1.0383	3.7147	23
1.0248	4.5722	1.0290	4.2425	1.0335	3.9583	1.0384	3.7108	22
1.0249	4.5663	1.0291	4.2375	1.0336	3.9539	1.0385	3.7070	21
1.0249	4.5604	1.0291	4.2324	1.0337	3.9495	1.0386	3.7031	20
1.0250	4.5545	1.0292	4.2273	1.0338	3.9451	1.0387	3.6993	19
1.0251	4.5486	1.0293	4.2223	1.0338	3.9408	1.0387	3.6955	18
1.0251	4.5428	1.0293	4.2173	1.0339	3.9364	1.0388	3.6917	17
1.0252	4.5369	1.0294	4.2122	1.0340	3.9320	1.0389	3.6878	16
1.0253	4.5311	1.0295	4.2072	1.0341	3.9277	1.0390	3.6840	15
1.0253	4.5253	1.0296	4.2022	1.0341	3.9234	1.0391	3.6802	14
1.0254	4.5195	1.0296	4.1972	1.0342	3.9190	1.0392	3.6765	13
1.0255	4.5137	1.0297	4.1923	1.0343	3.9147	1.0393	3.6727	12
1.0255	4.5079	1.0298	4.1873	1.0344	3.9104	1.0393	3.6689	11
1.0256	4.5021	1.0299	4.1824	1.0345	3.9061	1.0394	3.6651	10
1.0257	4.4964	1.0299	4.1774	1.0345	3.9018	1.0395	3.6614	9
1.0257	4.4907	1.0300	4.1725	1.0346	3.8976	1.0396	3.6576	8
1.0258	4.4850	1.0301	4.1676	1.0347	3.8933	1.0397	3.6539	7
1.0259	4.4793	1.0302	4.1627	1.0348	3.8890	1.0398	3.6502	6
1.0260	4.4736	1.0302	4.1578	1.0349	3.8848	1.0399	3.6464	5
1.0260	4.4679	1.0303	4.1529	1.0349	3.8805	1.0399	3.6427	4
1.0261	4.4623	1.0304	4.1481	1.0350	3.8763	1.0400	3.6390	3
1.0262	4.4566	1.0305	4.1432	1.0351	3.8721	1.0401	3.6353	2
1.0262	4.4510	1.0305	4.1384	1.0352	3.8679	1.0402	3.6316	1
1.0263	4.4454	1.0306	4.1336	1.0353	3.8637	1.0403	3.6280	0
Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
77°		76°		75°		74°		

′	16° Sec.	16° Co-sec.	17° Sec.	17° Co-sec.	18° Sec.	18° Co-sec.	19° Sec.
0	1.0403	3.6279	1.0457	3.4203	1.0515	3.2361	1.0576
1	1.0404	3.6243	1.0458	3.4170	1.0516	3.2332	1.0577
2	1.0405	3.6206	1.0459	3.4138	1.0517	3.2303	1.0578
3	1.0406	3.6169	1.0460	3.4106	1.0518	3.2274	1.0579
4	1.0406	3.6133	1.0461	3.4073	1.0519	3.2245	1.0580
5	1.0407	3.6096	1.0461	3.4041	1.0520	3.2216	1.0581
6	1.0408	3.6060	1.0462	3.4009	1.0521	3.2188	1.0582
7	1.0409	3.6024	1.0463	3.3977	1.0522	3.2159	1.0584
8	1.0410	3.5987	1.0464	3.3945	1.0523	3.2131	1.0585
9	1.0411	3.5951	1.0465	3.3913	1.0524	3.2102	1.0586
10	1.0412	3.5915	1.0466	3.3881	1.0525	3.2074	1.0587
11	1.0413	3.5879	1.0467	3.3849	1.0526	3.2045	1.0588
12	1.0413	3.5843	1.0468	3.3817	1.0527	3.2017	1.0589
13	1.0414	3.5807	1.0469	3.3785	1.0528	3.1989	1.0590
14	1.0415	3.5772	1.0470	3.3754	1.0529	3.1960	1.0591
15	1.0416	3.5736	1.0471	3.3722	1.0530	3.1932	1.0592
16	1.0417	3.5700	1.0472	3.3690	1.0531	3.1904	1.0593
17	1.0418	3.5665	1.0473	3.3659	1.0532	3.1876	1.0594
18	1.0419	3.5629	1.0474	3.3627	1.0533	3.1848	1.0595
19	1.0420	3.5594	1.0475	3.3596	1.0534	3.1820	1.0596
20	1.0420	3.5559	1.0476	3.3565	1.0535	3.1792	1.0598
21	1.0421	3.5523	1.0477	3.3534	1.0536	3.1764	1.0599
22	1.0422	3.5488	1.0478	3.3502	1.0537	3.1736	1.0600
23	1.0423	3.5453	1.0478	3.3471	1.0538	3.1708	1.0601
24	1.0424	3.5418	1.0479	3.3440	1.0539	3.1681	1.0602
25	1.0425	3.5383	1.0480	3.3409	1.0540	3.1653	1.0603
26	1.0426	3.5348	1.0481	3.3378	1.0541	3.1625	1.0604
27	1.0427	3.5313	1.0482	3.3347	1.0542	3.1598	1.0605
28	1.0428	3.5279	1.0483	3.3316	1.0543	3.1570	1.0606
29	1.0428	3.5244	1.0484	3.3286	1.0544	3.1543	1.0607
30	1.0429	3.5209	1.0485	3.3255	1.0545	3.1515	1.0608
31	1.0430	3.5175	1.0486	3.3224	1.0546	3.1488	1.0609
32	1.0431	3.5140	1.0487	3.3194	1.0547	3.1461	1.0611
33	1.0432	3.5106	1.0488	3.3163	1.0548	3.1433	1.0612
34	1.0433	3.5072	1.0489	3.3133	1.0549	3.1406	1.0613
35	1.0434	3.5037	1.0490	3.3102	1.0550	3.1379	1.0614
36	1.0435	3.5003	1.0491	3.3072	1.0551	3.1352	1.0615
37	1.0436	3.4969	1.0492	3.3042	1.0552	3.1325	1.0616
38	1.0437	3.4935	1.0493	3.3011	1.0553	3.1298	1.0617
39	1.0438	3.4901	1.0494	3.2981	1.0554	3.1271	1.0618
40	1.0438	3.4867	1.0495	3.2951	1.0555	3.1244	1.0619
41	1.0439	3.4833	1.0496	3.2921	1.0556	3.1217	1.0620
42	1.0440	3.4799	1.0497	3.2891	1.0557	3.1190	1.0622
43	1.0441	3.4766	1.0498	3.2861	1.0558	3.1163	1.0623
44	1.0442	3.4732	1.0499	3.2831	1.0559	3.1137	1.0624
45	1.0443	3.4698	1.0500	3.2801	1.0560	3.1110	1.0625
46	1.0444	3.4665	1.0501	3.2772	1.0561	3.1083	1.0626
47	1.0445	3.4632	1.0502	3.2742	1.0562	3.1057	1.0627
48	1.0446	3.4598	1.0503	3.2712	1.0563	3.1030	1.0628
49	1.0447	3.4565	1.0504	3.2683	1.0565	3.1004	1.0629
50	1.0448	3.4532	1.0505	3.2653	1.0566	3.0977	1.0630
51	1.0448	3.4498	1.0506	3.2624	1.0567	3.0951	1.0632
52	1.0449	3.4465	1.0507	3.2594	1.0568	3.0925	1.0633
53	1.0450	3.4432	1.0508	3.2565	1.0569	3.0898	1.0634
54	1.0451	3.4399	1.0509	3.2535	1.0570	3.0872	1.0635
55	1.0452	3.4366	1.0510	3.2506	1.0571	3.0846	1.0636
56	1.0453	3.4334	1.0511	3.2477	1.0572	3.0820	1.0637
57	1.0454	3.4301	1.0512	3.2448	1.0573	3.0793	1.0638
58	1.0455	3.4268	1.0513	3.2419	1.0574	3.0767	1.0639
59	1.0456	3.4236	1.0514	3.2390	1.0575	3.0741	1.0641
60	1.0457	3.4203	1.0515	3.2361	1.0576	3.0715	1.0642
′	73° Co-sec.	73° Sec.	72° Co-sec.	72° Sec.	71° Co-sec.	71° Sec.	70° Co-sec.

′	20° Sec.	20° Co-sec.	21° Sec.	21° Co-sec.	22° Sec.	22° Co-sec.	23° Sec.	23° Co-sec.	′
0	1.0642	2.9238	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	60
1	1.0643	2.9215	1.0713	2.7883	1.0787	2.6675	1.0865	2.5575	59
2	1.0644	2.9191	1.0714	2.7862	1.0788	2.6656	1.0866	2.5558	58
3	1.0645	2.9168	1.0715	2.7841	1.0789	2.6637	1.0868	2.5540	57
4	1.0646	2.9145	1.0716	2.7820	1.0790	2.6618	1.0869	2.5523	56
5	1.0647	2.9122	1.0717	2.7799	1.0792	2.6599	1.0870	2.5506	55
6	1.0648	2.9098	1.0719	2.7778	1.0793	2.6580	1.0872	2.5488	54
7	1.0650	2.9075	1.0720	2.7757	1.0794	2.6561	1.0873	2.5471	53
8	1.0651	2.9052	1.0721	2.7736	1.0795	2.6542	1.0874	2.5453	52
9	1.0652	2.9029	1.0722	2.7715	1.0797	2.6523	1.0876	2.5436	51
10	1.0653	2.9006	1.0723	2.7694	1.0798	2.6504	1.0877	2.5419	50
11	1.0654	2.8983	1.0725	2.7674	1.0799	2.6485	1.0878	2.5402	49
12	1.0655	2.8960	1.0726	2.7653	1.0801	2.6466	1.0880	2.5384	48
13	1.0656	2.8937	1.0727	2.7632	1.0802	2.6447	1.0881	2.5367	47
14	1.0658	2.8915	1.0728	2.7611	1.0803	2.6428	1.0882	2.5350	46
15	1.0659	2.8892	1.0729	2.7591	1.0804	2.6410	1.0884	2.5333	45
16	1.0660	2.8869	1.0731	2.7570	1.0806	2.6391	1.0885	2.5316	44
17	1.0661	2.8846	1.0732	2.7550	1.0807	2.6372	1.0886	2.5299	43
18	1.0662	2.8824	1.0733	2.7529	1.0808	2.6353	1.0888	2.5281	42
19	1.0663	2.8801	1.0734	2.7509	1.0810	2.6335	1.0889	2.5264	41
20	1.0664	2.8778	1.0736	2.7488	1.0811	2.6316	1.0891	2.5247	40
21	1.0666	2.8756	1.0737	2.7468	1.0812	2.6297	1.0892	2.5230	39
22	1.0667	2.8733	1.0738	2.7447	1.0813	2.6279	1.0893	2.5213	38
23	1.0668	2.8711	1.0739	2.7427	1.0815	2.6260	1.0895	2.5196	37
24	1.0669	2.8688	1.0740	2.7406	1.0816	2.6242	1.0896	2.5179	36
25	1.0670	2.8666	1.0742	2.7386	1.0817	2.6223	1.0897	2.5163	35
26	1.0671	2.8644	1.0743	2.7366	1.0819	2.6205	1.0899	2.5146	34
27	1.0673	2.8621	1.0744	2.7346	1.0820	2.6186	1.0900	2.5129	33
28	1.0674	2.8599	1.0745	2.7325	1.0821	2.6168	1.0902	2.5112	32
29	1.0675	2.8577	1.0747	2.7305	1.0823	2.6150	1.0903	2.5095	31
30	1.0676	2.8554	1.0748	2.7285	1.0824	2.6131	1.0904	2.5078	30
31	1.0677	2.8532	1.0749	2.7265	1.0825	2.6113	1.0906	2.5062	29
32	1.0678	2.8510	1.0750	2.7245	1.0826	2.6095	1.0907	2.5045	28
33	1.0679	2.8488	1.0751	2.7225	1.0828	2.6076	1.0908	2.5028	27
34	1.0681	2.8466	1.0753	2.7205	1.0829	2.6058	1.0910	2.5011	26
35	1.0682	2.8444	1.0754	2.7185	1.0830	2.6040	1.0911	2.4995	25
36	1.0683	2.8422	1.0755	2.7165	1.0832	2.6022	1.0913	2.4978	24
37	1.0684	2.8400	1.0756	2.7145	1.0833	2.6003	1.0914	2.4961	23
38	1.0685	2.8378	1.0758	2.7125	1.0834	2.5985	1.0915	2.4945	22
39	1.0686	2.8356	1.0759	2.7105	1.0836	2.5967	1.0917	2.4928	21
40	1.0688	2.8334	1.0760	2.7085	1.0837	2.5949	1.0918	2.4912	20
41	1.0689	2.8312	1.0761	2.7065	1.0838	2.5931	1.0920	2.4895	19
42	1.0690	2.8290	1.0763	2.7045	1.0840	2.5913	1.0921	2.4879	18
43	1.0691	2.8269	1.0764	2.7026	1.0841	2.5895	1.0922	2.4862	17
44	1.0692	2.8247	1.0765	2.7006	1.0842	2.5877	1.0924	2.4846	16
45	1.0694	2.8225	1.0766	2.6986	1.0844	2.5859	1.0925	2.4830	15
46	1.0695	2.8204	1.0768	2.6967	1.0845	2.5841	1.0927	2.4813	14
47	1.0696	2.8182	1.0769	2.6947	1.0846	2.5823	1.0928	2.4797	13
48	1.0697	2.8160	1.0770	2.6927	1.0847	2.5805	1.0929	2.4780	12
49	1.0698	2.8139	1.0771	2.6908	1.0849	2.5787	1.0931	2.4764	11
50	1.0699	2.8117	1.0773	2.6888	1.0850	2.5770	1.0932	2.4748	10
51	1.0701	2.8096	1.0774	2.6869	1.0851	2.5752	1.0934	2.4731	9
52	1.0702	2.8074	1.0775	2.6849	1.0853	2.5734	1.0935	2.4715	8
53	1.0703	2.8053	1.0776	2.6830	1.0854	2.5716	1.0936	2.4699	7
54	1.0704	2.8032	1.0778	2.6810	1.0855	2.5699	1.0938	2.4683	6
55	1.0705	2.8010	1.0779	2.6791	1.0857	2.5681	1.0939	2.4666	5
56	1.0707	2.7989	1.0780	2.6772	1.0858	2.5663	1.0941	2.4650	4
57	1.0708	2.7968	1.0781	2.6752	1.0859	2.5646	1.0942	2.4634	3
58	1.0709	2.7947	1.0783	2.6733	1.0861	2.5628	1.0943	2.4618	2
59	1.0710	2.7925	1.0784	2.6714	1.0862	2.5610	1.0945	2.4602	1
60	1.0711	2.7904	1.0785	2.6695	1.0864	2.5593	1.0946	2.4586	0
′	69° Co-sec.	69° Sec.	68° Co-sec.	68° Sec.	67° Co-sec.	67° Sec.	66° Co-sec.	66° Sec.	′

′	24° Sec.	24° Co-sec.	25° Sec.	25° Co-sec.	26° Sec.	26° Co-sec.	27° Sec.
0	1.0946	2.4586	1.1034	2.3662	1.1126	2.2812	1.1223
1	1.0948	2.4570	1.1035	2.3647	1.1127	2.2798	1.1225
2	1.0949	2.4554	1.1037	2.3632	1.1129	2.2784	1.1226
3	1.0951	2.4538	1.1038	2.3618	1.1131	2.2771	1.1228
4	1.0952	2.4522	1.1040	2.3603	1.1132	2.2757	1.1230
5	1.0953	2.4506	1.1041	2.3588	1.1134	2.2744	1.1231
6	1.0955	2.4490	1.1043	2.3574	1.1135	2.2730	1.1233
7	1.0956	2.4474	1.1044	2.3559	1.1137	2.2717	1.1235
8	1.0958	2.4458	1.1046	2.3544	1.1139	2.2703	1.1237
9	1.0959	2.4442	1.1047	2.3530	1.1140	2.2690	1.1238
10	1.0961	2.4426	1.1049	2.3515	1.1142	2.2676	1.1240
11	1.0962	2.4411	1.1050	2.3501	1.1143	2.2663	1.1242
12	1.0963	2.4395	1.1052	2.3486	1.1145	2.2650	1.1243
13	1.0965	2.4379	1.1053	2.3472	1.1147	2.2636	1.1245
14	1.0966	2.4363	1.1055	2.3457	1.1148	2.2623	1.1247
15	1.0968	2.4347	1.1056	2.3443	1.1150	2.2610	1.1248
16	1.0969	2.4332	1.1058	2.3428	1.1151	2.2596	1.1250
17	1.0971	2.4316	1.1059	2.3414	1.1153	2.2583	1.1252
18	1.0972	2.4300	1.1061	2.3399	1.1155	2.2570	1.1253
19	1.0973	2.4285	1.1062	2.3385	1.1156	2.2556	1.1255
20	1.0975	2.4269	1.1064	2.3371	1.1158	2.2543	1.1257
21	1.0976	2.4254	1.1065	2.3356	1.1159	2.2530	1.1258
22	1.0978	2.4238	1.1067	2.3342	1.1161	2.2517	1.1260
23	1.0979	2.4222	1.1068	2.3328	1.1163	2.2503	1.1262
24	1.0981	2.4207	1.1070	2.3313	1.1164	2.2490	1.1264
25	1.0982	2.4191	1.1072	2.3299	1.1166	2.2477	1.1265
26	1.0984	2.4176	1.1073	2.3285	1.1167	2.2464	1.1267
27	1.0985	2.4160	1.1075	2.3271	1.1169	2.2451	1.1269
28	1.0986	2.4145	1.1076	2.3256	1.1171	2.2438	1.1270
29	1.0988	2.4130	1.1078	2.3242	1.1172	2.2425	1.1272
30	1.0989	2.4114	1.1079	2.3228	1.1174	2.2411	1.1274
31	1.0991	2.4099	1.1081	2.3214	1.1176	2.2398	1.1275
32	1.0992	2.4083	1.1082	2.3200	1.1177	2.2385	1.1277
33	1.0994	2.4068	1.1084	2.3186	1.1179	2.2372	1.1279
34	1.0995	2.4053	1.1085	2.3172	1.1180	2.2359	1.1281
35	1.0997	2.4037	1.1087	2.3158	1.1182	2.2346	1.1282
36	1.0998	2.4022	1.1088	2.3143	1.1184	2.2333	1.1284
37	1.1000	2.4007	1.1090	2.3129	1.1185	2.2320	1.1286
38	1.1001	2.3992	1.1092	2.3115	1.1187	2.2307	1.1287
39	1.1003	2.3976	1.1093	2.3101	1.1189	2.2294	1.1289
40	1.1004	2.3961	1.1095	2.3087	1.1190	2.2282	1.1291
41	1.1005	2.3946	1.1096	2.3073	1.1192	2.2269	1.1293
42	1.1007	2.3931	1.1098	2.3059	1.1193	2.2256	1.1294
43	1.1008	2.3916	1.1099	2.3046	1.1195	2.2243	1.1296
44	1.1010	2.3901	1.1101	2.3032	1.1197	2.2230	1.1298
45	1.1011	2.3886	1.1102	2.3018	1.1198	2.2217	1.1299
46	1.1013	2.3871	1.1104	2.3004	1.1200	2.2204	1.1301
47	1.1014	2.3856	1.1106	2.2990	1.1202	2.2192	1.1303
48	1.1016	2.3841	1.1107	2.2976	1.1203	2.2179	1.1305
49	1.1017	2.3826	1.1109	2.2962	1.1205	2.2166	1.1306
50	1.1019	2.3811	1.1110	2.2949	1.1207	2.2153	1.1308
51	1.1020	2.3796	1.1112	2.2935	1.1208	2.2141	1.1310
52	1.1022	2.3781	1.1113	2.2921	1.1210	2.2128	1.1312
53	1.1023	2.3766	1.1115	2.2907	1.1212	2.2115	1.1313
54	1.1025	2.3751	1.1116	2.2894	1.1213	2.2103	1.1315
55	1.1026	2.3736	1.1118	2.2880	1.1215	2.2090	1.1317
56	1.1028	2.3721	1.1120	2.2866	1.1217	2.2077	1.1319
57	1.1029	2.3706	1.1121	2.2853	1.1218	2.2065	1.1320
58	1.1031	2.3691	1.1123	2.2839	1.1220	2.2052	1.1322
59	1.1032	2.3677	1.1124	2.2825	1.1222	2.2039	1.1324
60	1.1034	2.3662	1.1126	2.2812	1.1223	2.2027	1.1326
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.
	65°		64°		63°		62°

	28°		29°		30°		31°		
′	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	′
0	1.1326	2.1300	1.1433	2.0627	1.1547	2.0000	1.1666	1.9416	60
1	1.1327	2.1289	1.1435	2.0616	1.1549	1.9990	1.1668	1.9407	59
2	1.1329	2.1277	1.1437	2.0605	1.1551	1.9980	1.1670	1.9397	58
3	1.1331	2.1266	1.1439	2.0594	1.1553	1.9970	1.1672	1.9388	57
4	1.1333	2.1254	1.1441	2.0583	1.1555	1.9960	1.1674	1.9378	56
5	1.1334	2.1243	1.1443	2.0573	1.1557	1.9950	1.1676	1.9369	55
6	1.1336	2.1231	1.1445	2.0562	1.1559	1.9940	1.1678	1.9360	54
7	1.1338	2.1219	1.1446	2.0551	1.1561	1.9930	1.1681	1.9350	53
8	1.1340	2.1208	1.1448	2.0540	1.1562	1.9920	1.1683	1.9341	52
9	1.1341	2.1196	1.1450	2.0530	1.1564	1.9910	1.1685	1.9332	51
10	1.1343	2.1185	1.1452	2.0519	1.1566	1.9900	1.1687	1.9322	50
11	1.1345	2.1173	1.1454	2.0508	1.1568	1.9890	1.1689	1.9313	49
12	1.1347	2.1162	1.1456	2.0498	1.1570	1.9880	1.1691	1.9304	48
13	1.1349	2.1150	1.1458	2.0487	1.1572	1.9870	1.1693	1.9295	47
14	1.1350	2.1139	1.1459	2.0476	1.1574	1.9860	1.1695	1.9285	46
15	1.1352	2.1127	1.1461	2.0466	1.1576	1.9850	1.1697	1.9276	45
16	1.1354	2.1116	1.1463	2.0455	1.1578	1.9840	1.1699	1.9267	44
17	1.1356	2.1104	1.1465	2.0444	1.1580	1.9830	1.1701	1.9258	43
18	1.1357	2.1093	1.1467	2.0434	1.1582	1.9820	1.1703	1.9248	42
19	1.1359	2.1082	1.1469	2.0423	1.1584	1.9811	1.1705	1.9239	41
20	1.1361	2.1070	1.1471	2.0413	1.1586	1.9801	1.1707	1.9230	40
21	1.1363	2.1059	1.1473	2.0402	1.1588	1.9791	1.1709	1.9221	39
22	1.1365	2.1048	1.1474	2.0392	1.1590	1.9781	1.1712	1.9212	38
23	1.1366	2.1036	1.1476	2.0381	1.1592	1.9771	1.1714	1.9203	37
24	1.1368	2.1025	1.1478	2.0370	1.1594	1.9761	1.1716	1.9193	36
25	1.1370	2.1014	1.1480	2.0360	1.1596	1.9752	1.1718	1.9184	35
26	1.1372	2.1002	1.1482	2.0349	1.1598	1.9742	1.1720	1.9175	34
27	1.1373	2.0991	1.1484	2.0339	1.1600	1.9732	1.1722	1.9166	33
28	1.1375	2.0980	1.1486	2.0329	1.1602	1.9722	1.1724	1.9157	32
29	1.1377	2.0969	1.1488	2.0318	1.1604	1.9713	1.1726	1.9148	31
30	1.1379	2.0957	1.1489	2.0308	1.1606	1.9703	1.1728	1.9139	30
31	1.1381	2.0946	1.1491	2.0297	1.1608	1.9693	1.1730	1.9130	29
32	1.1382	2.0935	1.1493	2.0287	1.1610	1.9683	1.1732	1.9121	28
33	1.1384	2.0924	1.1495	2.0276	1.1612	1.9674	1.1734	1.9112	27
34	1.1386	2.0912	1.1497	2.0266	1.1614	1.9664	1.1737	1.9102	26
35	1.1388	2.0901	1.1499	2.0256	1.1616	1.9654	1.1739	1.9093	25
36	1.1390	2.0890	1.1501	2.0245	1.1618	1.9645	1.1741	1.9084	24
37	1.1391	2.0879	1.1503	2.0235	1.1620	1.9635	1.1743	1.9075	23
38	1.1393	2.0868	1.1505	2.0224	1.1622	1.9625	1.1745	1.9066	22
39	1.1395	2.0857	1.1507	2.0214	1.1624	1.9616	1.1747	1.9057	21
40	1.1397	2.0846	1.1508	2.0204	1.1626	1.9606	1.1749	1.9048	20
41	1.1399	2.0835	1.1510	2.0194	1.1628	1.9596	1.1751	1.9039	19
42	1.1401	2.0824	1.1512	2.0183	1.1630	1.9587	1.1753	1.9030	18
43	1.1402	2.0812	1.1514	2.0173	1.1632	1.9577	1.1756	1.9021	17
44	1.1404	2.0801	1.1516	2.0163	1.1634	1.9568	1.1758	1.9013	16
45	1.1406	2.0790	1.1518	2.0152	1.1636	1.9558	1.1760	1.9004	15
46	1.1408	2.0779	1.1520	2.0142	1.1638	1.9549	1.1762	1.8995	14
47	1.1410	2.0768	1.1522	2.0132	1.1640	1.9539	1.1764	1.8986	13
48	1.1411	2.0757	1.1524	2.0122	1.1642	1.9530	1.1766	1.8977	12
49	1.1413	2.0746	1.1526	2.0111	1.1644	1.9520	1.1768	1.8968	11
50	1.1415	2.0735	1.1528	2.0101	1.1646	1.9510	1.1770	1.8959	10
51	1.1417	2.0725	1.1530	2.0091	1.1648	1.9501	1.1772	1.8950	9
52	1.1419	2.0714	1.1531	2.0081	1.1650	1.9491	1.1775	1.8941	8
53	1.1421	2.0703	1.1533	2.0071	1.1652	1.9482	1.1777	1.8932	7
54	1.1422	2.0692	1.1535	2.0061	1.1654	1.9473	1.1779	1.8924	6
55	1.1424	2.0681	1.1537	2.0050	1.1656	1.9463	1.1781	1.8915	5
56	1.1426	2.0670	1.1539	2.0040	1.1658	1.9454	1.1783	1.8906	4
57	1.1428	2.0659	1.1541	2.0030	1.1660	1.9444	1.1785	1.8897	3
58	1.1430	2.0648	1.1543	2.0020	1.1662	1.9435	1.1787	1.8888	2
59	1.1432	2.0637	1.1545	2.0010	1.1664	1.9425	1.1790	1.8879	1
60	1.1433	2.0627	1.1547	2.0000	1.1666	1.9416	1.1792	1.8871	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	61°		60°		59°		58°		

′	32° Sec.	32° Co-sec.	33° Sec.	33° Co-sec.	34° Sec.	34° Co-sec.	35° Sec.
0	1.1792	1.8871	1.1924	1.8361	1.2062	1.7883	1.2208
1	1.1794	1.8862	1.1926	1.8352	1.2064	1.7875	1.2210
2	1.1796	1.8853	1.1928	1.8344	1.2067	1.7867	1.2213
3	1.1798	1.8844	1.1930	1.8336	1.2069	1.7860	1.2215
4	1.1800	1.8836	1.1933	1.8328	1.2072	1.7852	1.2218
5	1.1802	1.8827	1.1935	1.8320	1.2074	1.7844	1.2220
6	1.1805	1.8818	1.1937	1.8311	1.2076	1.7837	1.2223
7	1.1807	1.8809	1.1939	1.8303	1.2079	1.7829	1.2225
8	1.1809	1.8801	1.1942	1.8295	1.2081	1.7821	1.2228
9	1.1811	1.8792	1.1944	1.8287	1.2083	1.7814	1.2230
10	1.1813	1.8783	1.1946	1.8279	1.2086	1.7806	1.2233
11	1.1815	1.8775	1.1948	1.8271	1.2088	1.7798	1.2235
12	1.1818	1.8766	1.1951	1.8263	1.2091	1.7791	1.2238
13	1.1820	1.8757	1.1953	1.8255	1.2093	1.7783	1.2240
14	1.1822	1.8749	1.1955	1.8246	1.2095	1.7776	1.2243
15	1.1824	1.8740	1.1958	1.8238	1.2098	1.7768	1.2245
16	1.1826	1.8731	1.1960	1.8230	1.2100	1.7760	1.2248
17	1.1828	1.8723	1.1962	1.8222	1.2103	1.7753	1.2250
18	1.1831	1.8714	1.1964	1.8214	1.2105	1.7745	1.2253
19	1.1833	1.8706	1.1967	1.8206	1.2107	1.7738	1.2255
20	1.1835	1.8697	1.1969	1.8198	1.2110	1.7730	1.2258
21	1.1837	1.8688	1.1971	1.8190	1.2112	1.7723	1.2260
22	1.1839	1.8680	1.1974	1.8182	1.2115	1.7715	1.2263
23	1.1841	1.8671	1.1976	1.8174	1.2117	1.7708	1.2265
24	1.1844	1.8663	1.1978	1.8166	1.2119	1.7700	1.2268
25	1.1846	1.8654	1.1980	1.8158	1.2122	1.7693	1.2270
26	1.1848	1.8646	1.1983	1.8150	1.2124	1.7685	1.2273
27	1.1850	1.8637	1.1985	1.8142	1.2127	1.7678	1.2276
28	1.1852	1.8629	1.1987	1.8134	1.2129	1.7670	1.2278
29	1.1855	1.8620	1.1990	1.8126	1.2132	1.7663	1.2281
30	1.1857	1.8611	1.1992	1.8118	1.2134	1.7655	1.2283
31	1.1859	1.8603	1.1994	1.8110	1.2136	1.7648	1.2286
32	1.1861	1.8595	1.1997	1.8102	1.2139	1.7640	1.2288
33	1.1863	1.8586	1.1999	1.8094	1.2141	1.7633	1.2291
34	1.1866	1.8578	1.2001	1.8086	1.2144	1.7625	1.2293
35	1.1868	1.8569	1.2004	1.8078	1.2146	1.7618	1.2296
36	1.1870	1.8561	1.2006	1.8070	1.2149	1.7610	1.2298
37	1.1872	1.8552	1.2008	1.8062	1.2151	1.7603	1.2301
38	1.1874	1.8544	1.2010	1.8054	1.2153	1.7596	1.2304
39	1.1877	1.8535	1.2013	1.8047	1.2156	1.7588	1.2306
40	1.1879	1.8527	1.2015	1.8039	1.2158	1.7581	1.2309
41	1.1881	1.8519	1.2017	1.8031	1.2161	1.7573	1.2311
42	1.1883	1.8510	1.2020	1.8023	1.2163	1.7566	1.2314
43	1.1886	1.8502	1.2022	1.8015	1.2166	1.7559	1.2316
44	1.1888	1.8493	1.2024	1.8007	1.2168	1.7551	1.2319
45	1.1890	1.8485	1.2027	1.7999	1.2171	1.7544	1.2322
46	1.1892	1.8477	1.2029	1.7992	1.2173	1.7537	1.2324
47	1.1894	1.8468	1.2031	1.7984	1.2175	1.7529	1.2327
48	1.1897	1.8460	1.2034	1.7976	1.2178	1.7522	1.2329
49	1.1899	1.8452	1.2036	1.7968	1.2180	1.7514	1.2332
50	1.1901	1.8443	1.2039	1.7960	1.2183	1.7507	1.2335
51	1.1903	1.8435	1.2041	1.7953	1.2185	1.7500	1.2337
52	1.1906	1.8427	1.2043	1.7945	1.2188	1.7493	1.2340
53	1.1908	1.8418	1.2046	1.7937	1.2190	1.7485	1.2342
54	1.1910	1.8410	1.2048	1.7929	1.2193	1.7478	1.2345
55	1.1912	1.8402	1.2050	1.7921	1.2195	1.7471	1.2348
56	1.1915	1.8394	1.2053	1.7914	1.2198	1.7463	1.2350
57	1.1917	1.8385	1.2055	1.7906	1.2200	1.7456	1.2353
58	1.1919	1.8377	1.2057	1.7898	1.2203	1.7449	1.2355
59	1.1921	1.8369	1.2060	1.7891	1.2205	1.7442	1.2358
60	1.1924	1.8361	1.2062	1.7883	1.2208	1.7434	1.2361
′	Co-sec. 57°	Sec. 57°	Co-sec. 56°	Sec. 56°	Co-sec. 55°	Sec. 55°	Co-sec. 54°

′	36°		37°		38°		39°		′
	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	
0	1.2361	1.7013	1.2521	1.6616	1.2690	1.6243	1.2867	1.5890	60
1	1.2363	1.7006	1.2524	1.6610	1.2693	1.6237	1.2871	1.5884	59
2	1.2366	1.6999	1.2527	1.6603	1.2696	1.6231	1.2874	1.5879	58
3	1.2368	1.6993	1.2530	1.6597	1.2699	1.6224	1.2877	1.5873	57
4	1.2371	1.6986	1.2532	1.6591	1.2702	1.6218	1.2880	1.5867	56
5	1.2374	1.6979	1.2535	1.6584	1.2705	1.6212	1.2883	1.5862	55
6	1.2376	1.6972	1.2538	1.6578	1.2707	1.6206	1.2886	1.5856	54
7	1.2379	1.6965	1.2541	1.6572	1.2710	1.6200	1.2889	1.5850	53
8	1.2382	1.6959	1.2543	1.6565	1.2713	1.6194	1.2892	1.5845	52
9	1.2384	1.6952	1.2546	1.6559	1.2716	1.6188	1.2895	1.5839	51
10	1.2387	1.6945	1.2549	1.6552	1.2719	1.6182	1.2898	1.5833	50
11	1.2390	1.6938	1.2552	1.6546	1.2722	1.6176	1.2901	1.5828	49
12	1.2392	1.6932	1.2554	1.6540	1.2725	1.6170	1.2904	1.5822	48
13	1.2395	1.6925	1.2557	1.6533	1.2728	1.6164	1.2907	1.5816	47
14	1.2397	1.6918	1.2560	1.6527	1.2731	1.6159	1.2910	1.5811	46
15	1.2400	1.6912	1.2563	1.6521	1.2734	1.6153	1.2913	1.5805	45
16	1.2403	1.6905	1.2565	1.6514	1.2737	1.6147	1.2916	1.5799	44
17	1.2405	1.6898	1.2568	1.6508	1.2739	1.6141	1.2919	1.5794	43
18	1.2408	1.6891	1.2571	1.6502	1.2742	1.6135	1.2922	1.5788	42
19	1.2411	1.6885	1.2574	1.6496	1.2745	1.6129	1.2926	1.5783	41
20	1.2413	1.6878	1.2577	1.6489	1.2748	1.6123	1.2929	1.5777	40
21	1.2416	1.6871	1.2579	1.6483	1.2751	1.6117	1.2932	1.5771	39
22	1.2419	1.6865	1.2582	1.6477	1.2754	1.6111	1.2935	1.5766	38
23	1.2421	1.6858	1.2585	1.6470	1.2757	1.6105	1.2938	1.5760	37
24	1.2424	1.6851	1.2588	1.6464	1.2760	1.6099	1.2941	1.5755	36
25	1.2427	1.6845	1.2591	1.6458	1.2763	1.6093	1.2944	1.5749	35
26	1.2429	1.6838	1.2593	1.6452	1.2766	1.6087	1.2947	1.5743	34
27	1.2432	1.6831	1.2596	1.6445	1.2769	1.6081	1.2950	1.5738	33
28	1.2435	1.6825	1.2599	1.6439	1.2772	1.6077	1.2953	1.5732	32
29	1.2437	1.6818	1.2602	1.6433	1.2775	1.6070	1.2956	1.5727	31
30	1.2440	1.6812	1.2605	1.6427	1.2778	1.6064	1.2960	1.5721	30
31	1.2443	1.6805	1.2607	1.6420	1.2781	1.6058	1.2963	1.5716	29
32	1.2445	1.6798	1.2610	1.6414	1.2784	1.6052	1.2966	1.5710	28
33	1.2448	1.6792	1.2613	1.6408	1.2787	1.6046	1.2969	1.5705	27
34	1.2451	1.6785	1.2616	1.6402	1.2790	1.6040	1.2972	1.5699	26
35	1.2453	1.6779	1.2619	1.6396	1.2793	1.6034	1.2975	1.5694	25
36	1.2456	1.6772	1.2622	1.6390	1.2795	1.6029	1.2978	1.5688	24
37	1.2459	1.6766	1.2624	1.6383	1.2798	1.6023	1.2981	1.5683	23
38	1.2461	1.6759	1.2627	1.6377	1.2801	1.6017	1.2985	1.5677	22
39	1.2464	1.6752	1.2630	1.6371	1.2804	1.6011	1.2988	1.5672	21
40	1.2467	1.6746	1.2633	1.6365	1.2807	1.6005	1.2991	1.5666	20
41	1.2470	1.6739	1.2636	1.6359	1.2810	1.6000	1.2994	1.5661	19
42	1.2472	1.6733	1.2639	1.6352	1.2813	1.5994	1.2997	1.5655	18
43	1.2475	1.6726	1.2641	1.6346	1.2816	1.5988	1.3000	1.5650	17
44	1.2478	1.6720	1.2644	1.6340	1.2819	1.5982	1.3003	1.5644	16
45	1.2480	1.6713	1.2647	1.6334	1.2822	1.5976	1.3006	1.5639	15
46	1.2483	1.6707	1.2650	1.6328	1.2825	1.5971	1.3010	1.5633	14
47	1.2486	1.6700	1.2653	1.6322	1.2828	1.5965	1.3013	1.5628	13
48	1.2488	1.6694	1.2656	1.6316	1.2831	1.5959	1.3016	1.5622	12
49	1.2490	1.6687	1.2659	1.6310	1.2834	1.5953	1.3019	1.5617	11
50	1.2494	1.6681	1.2661	1.6303	1.2837	1.5947	1.3022	1.5611	10
51	1.2497	1.6674	1.2664	1.6297	1.2840	1.5942	1.3025	1.5606	9
52	1.2499	1.6668	1.2667	1.6291	1.2843	1.5936	1.3029	1.5600	8
53	1.2502	1.6661	1.2670	1.6285	1.2846	1.5930	1.3032	1.5595	7
54	1.2505	1.6655	1.2673	1.6279	1.2849	1.5924	1.3035	1.5590	6
55	1.2508	1.6648	1.2676	1.6273	1.2852	1.5919	1.3038	1.5584	5
56	1.2510	1.6642	1.2679	1.6267	1.2855	1.5913	1.3041	1.5579	4
57	1.2513	1.6636	1.2681	1.6261	1.2858	1.5907	1.3044	1.5573	3
58	1.2516	1.6629	1.2684	1.6255	1.2861	1.5901	1.3048	1.5568	2
59	1.2519	1.6623	1.2687	1.6249	1.2864	1.5896	1.3051	1.5563	1
60	1.2521	1.6616	1.2690	1.6243	1.2867	1.5890	1.3054	1.5557	0
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	′
	53°		52°		51°		50°		

′	40°		41°		42°		43°
	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.
0	1.3054	1.5557	1.3250	1.5243	1.3456	1.4945	1.3673
1	1.3057	1.5552	1.3253	1.5237	1.3460	1.4940	1.3677
2	1.3060	1.5546	1.3257	1.5232	1.3463	1.4935	1.3681
3	1.3064	1.5541	1.3260	1.5227	1.3467	1.4930	1.3684
4	1.3067	1.5536	1.3264	1.5222	1.3470	1.4925	1.3688
5	1.3070	1.5530	1.3267	1.5217	1.3474	1.4921	1.3692
6	1.3073	1.5525	1.3270	1.5212	1.3477	1.4916	1.3695
7	1.3076	1.5520	1.3274	1.5207	1.3481	1.4911	1.3699
8	1.3080	1.5514	1.3277	1.5202	1.3485	1.4906	1.3703
9	1.3083	1.5509	1.3280	1.5197	1.3488	1.4901	1.3707
10	1.3086	1.5503	1.3284	1.5192	1.3492	1.4897	1.3710
11	1.3089	1.5498	1.3287	1.5187	1.3495	1.4892	1.3714
12	1.3093	1.5493	1.3290	1.5182	1.3499	1.4887	1.3718
13	1.3096	1.5487	1.3294	1.5177	1.3502	1.4882	1.3722
14	1.3099	1.5482	1.3297	1.5172	1.3506	1.4877	1.3725
15	1.3102	1.5477	1.3301	1.5167	1.3509	1.4873	1.3729
16	1.3105	1.5472	1.3304	1.5162	1.3513	1.4868	1.3733
17	1.3109	1.5466	1.3307	1.5156	1.3517	1.4863	1.3737
18	1.3112	1.5461	1.3311	1.5151	1.3520	1.4858	1.3740
19	1.3115	1.5456	1.3314	1.5146	1.3524	1.4854	1.3744
20	1.3118	1.5450	1.3318	1.5141	1.3527	1.4849	1.3748
21	1.3122	1.5445	1.3321	1.5136	1.3531	1.4844	1.3752
22	1.3125	1.5440	1.3324	1.5131	1.3534	1.4839	1.3756
23	1.3128	1.5434	1.3328	1.5126	1.3538	1.4835	1.3759
24	1.3131	1.5429	1.3331	1.5121	1.3542	1.4830	1.3763
25	1.3134	1.5424	1.3335	1.5116	1.3545	1.4825	1.3767
26	1.3138	1.5419	1.3338	1.5111	1.3549	1.4821	1.3771
27	1.3141	1.5413	1.3342	1.5106	1.3553	1.4816	1.3774
28	1.3144	1.5408	1.3345	1.5102	1.3556	1.4811	1.3778
29	1.3148	1.5403	1.3348	1.5097	1.3560	1.4806	1.3782
30	1.3151	1.5398	1.3352	1.5092	1.3563	1.4802	1.3786
31	1.3154	1.5392	1.3355	1.5087	1.3567	1.4797	1.3790
32	1.3157	1.5387	1.3359	1.5082	1.3571	1.4792	1.3794
33	1.3161	1.5382	1.3362	1.5077	1.3574	1.4788	1.3797
34	1.3164	1.5377	1.3366	1.5072	1.3578	1.4783	1.3801
35	1.3167	1.5371	1.3369	1.5067	1.3581	1.4778	1.3805
36	1.3170	1.5366	1.3373	1.5062	1.3585	1.4774	1.3809
37	1.3174	1.5361	1.3376	1.5057	1.3589	1.4769	1.3813
38	1.3177	1.5356	1.3379	1.5052	1.3592	1.4764	1.3816
39	1.3180	1.5351	1.3383	1.5047	1.3596	1.4760	1.3820
40	1.3184	1.5345	1.3386	1.5042	1.3600	1.4755	1.3824
41	1.3187	1.5340	1.3390	1.5037	1.3603	1.4750	1.3828
42	1.3190	1.5335	1.3393	1.5032	1.3607	1.4746	1.3832
43	1.3193	1.5330	1.3397	1.5027	1.3611	1.4741	1.3836
44	1.3197	1.5325	1.3400	1.5023	1.3614	1.4736	1.3839
45	1.3200	1.5319	1.3404	1.5018	1.3618	1.4732	1.3843
46	1.3203	1.5314	1.3407	1.5013	1.3622	1.4727	1.3847
47	1.3207	1.5309	1.3411	1.5008	1.3625	1.4723	1.3851
48	1.3210	1.5304	1.3414	1.5003	1.3629	1.4718	1.3855
49	1.3213	1.5299	1.3418	1.4998	1.3633	1.4713	1.3859
50	1.3217	1.5294	1.3421	1.4993	1.3636	1.4709	1.3863
51	1.3220	1.5289	1.3425	1.4988	1.3640	1.4704	1.3867
52	1.3223	1.5283	1.3428	1.4983	1.3644	1.4699	1.3870
53	1.3227	1.5278	1.3432	1.4979	1.3647	1.4695	1.3874
54	1.3230	1.5273	1.3435	1.4974	1.3651	1.4690	1.3878
55	1.3233	1.5268	1.3439	1.4969	1.3655	1.4686	1.3882
56	1.3237	1.5263	1.3442	1.4964	1.3658	1.4681	1.3886
57	1.3240	1.5258	1.3446	1.4959	1.3662	1.4676	1.3890
58	1.3243	1.5253	1.3449	1.4954	1.3666	1.4672	1.3894
59	1.3247	1.5248	1.3453	1.4950	1.3670	1.4667	1.3898
60	1.3250	1.5243	1.3456	1.4945	1.3673	1.4663	1.3902
′	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.	Sec.	Co-sec.
	49°		48°		47°		4

	44°				44°				44°		
′	Sec.	Co-sec.	′	′	Sec.	Co-sec.	′	′	Sec.	Co-sec.	′
0	1.3902	1.4396	60	21	1.3984	1.4305	39	41	1.4065	1.4221	19
1	1.3905	1.4391	59	22	1.3988	1.4301	38	42	1.4069	1.4217	18
2	1.3909	1.4387	58	23	1.3992	1.4297	37	43	1.4073	1.4212	17
3	1.3913	1.4382	57	24	1.3996	1.4292	36	44	1.4077	1.4208	16
4	1.3917	1.4378	56	25	1.4000	1.4288	35	45	1.4081	1.4204	15
5	1.3921	1.4374	55	26	1.4004	1.4284	34	46	1.4085	1.4200	14
6	1.3925	1.4370	54	27	1.4008	1.4280	33	47	1.4089	1.4196	13
7	1.3929	1.4365	53	28	1.4012	1.4276	32	48	1.4093	1.4192	12
8	1.3933	1.4361	52	29	1.4016	1.4271	31	49	1.4097	1.4188	11
9	1.3937	1.4357	51	30	1.4020	1.4267	30	50	1.4101	1.4183	10
10	1.3941	1.4352	50	31	1.4024	1.4263	29	51	1.4105	1.4179	9
11	1.3945	1.4348	49	32	1.4028	1.4259	28	52	1.4109	1.4175	8
12	1.3949	1.4344	48	33	1.4032	1.4254	27	53	1.4113	1.4171	7
13	1.3953	1.4339	47	34	1.4036	1.4250	26	54	1.4117	1.4167	6
14	1.3957	1.4335	46	35	1.4040	1.4246	25	55	1.4122	1.4163	5
15	1.3960	1.4331	45	36	1.4044	1.4242	24	56	1.4126	1.4159	4
16	1.3964	1.4327	44	37	1.4048	1.4238	23	57	1.4130	1.4154	3
17	1.3968	1.4322	43	38	1.4052	1.4233	22	58	1.4134	1.4150	2
18	1.3972	1.4318	42	39	1.4056	1.4229	21	59	1.4138	1.4146	1
19	1.3976	1.4314	41	40	1.4060	1.4225	20	60	1.4142	1.4142	0
20	1.3980	1.4310	40								
′	Co-sec.	Sec.	′	′	Co-sec.	Sec.	′	′	Co-sec.	Sec.	′
	45°				45°				45°		

Table 61

N.	0	1	2	3	4	5	6	7	8
100	000000	0434	0868	1301	1734	2166	2598	3029	3461
101	4321	4751	5181	5609	6038	6466	6894	7321	7748
102	8600	9026	9451	9876	*0300	*0724	*1147	*1570	*1993
103	012837	3259	3680	4100	4521	4940	5360	5779	6197
104	7033	7451	7868	8284	8700	9116	9532	9947	*0361
105	021189	1603	2016	2428	2841	3252	3664	4075	4486
106	5306	5715	6125	6533	6942	7350	7757	8164	8571
107	9384	9789	*0195	*0600	*1004	*1408	*1812	*2216	*2619
108	033424	3826	4227	4628	5029	5430	5830	6230	6629
109	7426	7825	8223	8620	9017	9414	9811	*0207	*0602

N.	Diff.	1	2	3	4	5	6	7	8
PROPORTIONAL PARTS	434	43	87	130	174	217	260	304	347
	433	43	87	130	173	217	260	303	346
	432	43	86	130	173	216	259	302	346
	431	43	86	129	172	216	259	302	345
	430	43	86	129	172	215	258	301	344
	429	43	86	129	172	215	257	300	343
	428	43	86	128	171	214	257	300	342
	427	43	85	128	171	214	256	299	342
	426	43	85	128	170	213	256	298	341
	425	43	85	128	170	213	255	298	340
	424	42	85	127	170	212	254	297	339
	423	42	85	127	169	212	254	296	338
	422	42	84	127	169	211	253	295	338
	421	42	84	126	168	211	253	295	337
	420	42	84	126	168	210	252	294	336
	419	42	84	126	168	210	251	293	335
	418	42	84	125	167	209	251	293	334
	417	42	83	125	167	209	250	292	334
	416	42	83	125	166	208	250	291	333
	415	42	83	125	166	208	249	291	332
	414	41	83	124	166	207	248	290	331
	413	41	83	124	165	207	248	289	330
	412	41	82	124	165	206	247	288	330
	411	41	82	123	164	206	247	288	329
	410	41	82	123	164	205	246	287	328
	409	41	82	123	164	205	245	286	327
	408	41	82	122	163	204	245	286	326
	407	41	81	122	163	204	244	285	326
	406	41	81	122	162	203	244	284	325
	405	41	81	122	162	203	243	284	324
	404	40	81	121	162	202	242	283	323
	403	40	81	121	161	202	242	282	322
	402	40	80	121	161	201	241	281	322
	401	40	80	120	160	201	241	281	321
	400	40	80	120	160	200	240	280	320
	399	40	80	120	160	200	239	279	319
	398	40	80	119	159	199	239	279	318
	397	40	79	119	159	199	238	278	318
	396	40	79	119	158	198	238	277	317
	395	40	79	119	158	198	237	277	316
	394	39	79	118	158	197	236	276	315
	393	39	79	118	157	197	236	275	314
	392	39	78	118	157	196	235	274	314
	391	39	78	117	156	196	235	274	313
	390	39	78	117	156	195	234	273	312
	389	39	78	117	156	195	233	272	311
	388	39	78	116	155	194	233	272	310
	Diff.	1	2	3	4	5	6	7	8

[redacted]

0	1	2	3	4	[redacted]	6	7	8	[redacted]	Diff.
041393	1787	2182	2576	2969	3362	3755	4148	4540	4932	393
5323	5714	6105	6495	6885	7275	7664	8053	8442	8830	390
9218	9606	9993	*0380	*0766	*1153	*1538	*1924	*2309	*2694	386
053078	3463	3846	4230	4613	4996	5378	5760	6142	6524	383
6905	7286	7666	8046	8426	8805	9185	9563	9942	*0320	379
060698	1075	1452	1829	2206	2582	2958	3333	3709	4083	376
4458	4832	5206	5580	5953	6326	6699	7071	7443	7815	373
8186	8557	8928	9298	9668	*0038	*0407	*0776	*1145	*1514	370
071882	2250	2617	2985	3352	3718	4085	4451	4816	5182	366
5547	5912	6276	6640	7004	7368	7731	8094	8457	8819	363
079181	9543	9904	*0266	*0626	*0987	*1347	*1707	*2067	*2426	360
082785	3144	3503	3861	4219	4576	4934	5291	5647	6004	357
6360	6716	7071	7426	7781	8136	8490	8845	9198	9552	355
9905	*0258	*0611	*0963	*1315	*1667	*2018	*2370	*2721	*3071	352
093422	3772	4122	4471	4820	5169	5518	5866	6215	6562	349

Diff.	1	2	3	4	5	6	7	8	9	Diff.
387	39	77	116	155	194	232	271	310	348	387
386	39	77	116	154	193	232	270	309	347	386
385	39	77	116	154	193	231	270	308	347	385
384	38	77	115	154	192	230	269	307	346	384
383	38	77	115	153	192	230	268	306	345	383
382	38	76	115	153	191	229	267	306	344	382
381	38	76	114	152	191	229	267	305	343	381
380	38	76	114	152	190	228	266	304	342	380
379	38	76	114	152	190	227	265	303	341	379
378	38	76	113	151	189	227	265	302	340	378
377	38	75	113	151	189	226	264	302	339	377
376	38	75	113	150	188	226	263	301	338	376
375	38	75	113	150	188	225	263	300	338	375
374	37	75	112	150	187	224	262	299	337	374
373	37	75	112	149	187	224	261	298	336	373
372	37	74	112	149	186	223	260	298	335	372
371	37	74	111	148	186	223	260	297	334	371
370	37	74	111	148	185	222	259	296	333	370
369	37	74	111	148	185	221	258	295	332	369
368	37	74	110	147	184	221	258	294	331	368
367	37	73	110	147	184	220	257	294	330	367
366	37	73	110	146	183	220	256	293	329	366
365	37	73	110	146	183	219	256	292	329	365
364	36	73	109	146	182	218	255	291	328	364
363	36	73	109	145	182	218	254	290	327	363
362	36	72	109	145	181	217	253	290	326	362
361	36	72	108	144	181	217	253	289	325	361
360	36	72	108	144	180	216	252	288	324	360
359	36	72	108	144	180	215	251	287	323	359
358	36	72	107	143	179	215	251	286	322	358
357	36	71	107	143	179	214	250	286	321	357
356	36	71	107	142	178	214	249	285	320	356
355	36	71	107	142	178	213	249	284	320	355
354	35	71	106	142	177	212	248	283	319	354
353	35	71	106	141	177	212	247	282	318	353
352	35	70	106	141	176	211	246	282	317	[redacted]
351	35	70	105	140	176	211	246	281	316	351
350	35	70	105	140	175	210	245	280	315	350
349	35	70	105	140	175	209	244	279	314	349
348	35	70	104	139	174	209	244	278	313	348
347	35	69	104	139	174	208	243	278	312	347
Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8
125	096910	7257	7604	7951	8298	8644	8990	9335	9681
126	100371	0715	1059	1403	1747	2091	2434	2777	3119
127	3804	4146	4487	4828	5169	5510	5851	6191	6531
128	7210	7549	7888	8227	8565	8903	9241	9579	9916
129	110590	0926	1263	1599	1934	2270	2605	2940	3275
130	113943	4277	4611	4944	5278	5611	5943	6276	6608
131	7271	7603	7934	8265	8595	8926	9256	9586	9915
132	120574	0903	1231	1560	1888	2216	2544	2871	3198
133	3852	4178	4504	4830	5156	5481	5806	6131	6456
134	7105	7429	7753	8076	8399	8722	9045	9368	9690
135	130334	0655	0977	1298	1619	1939	2260	2580	2900
136	3539	3858	4177	4496	4814	5133	5451	5769	6086
137	6721	7037	7354	7671	7987	8303	8618	8934	9249
138	9879	*0194	*0508	*0822	*1136	*1450	*1763	*2076	*2389
139	143015	3327	3639	3951	4263	4574	4885	5196	5507

PROPORTIONAL PARTS

N.	Diff.	1	2	3	4	5	6	7	8
	347	35	69	104	139	174	208	243	278
	346	35	69	104	138	173	208	242	277
	345	35	69	104	138	173	207	242	276
	344	34	69	103	138	172	206	241	275
	343	34	69	103	137	172	206	240	274
	342	34	68	103	137	171	205	239	274
	341	34	68	102	136	171	205	239	273
	340	34	68	102	136	170	204	238	272
	339	34	68	102	136	170	203	237	271
	338	34	68	101	135	169	203	237	270
	337	34	67	101	135	169	202	236	270
	336	34	67	101	134	168	202	235	269
	335	34	67	101	134	168	201	255	268
	334	33	67	100	134	167	200	234	267
	333	33	67	100	133	167	200	233	266
	332	33	66	100	133	166	199	232	266
	331	33	66	99	132	166	199	232	265
	330	33	66	99	132	165	198	231	264
	329	33	66	99	132	165	197	230	263
	328	33	66	98	131	164	197	230	262
	327	33	65	98	131	164	196	229	262
	326	33	65	98	130	163	196	228	261
	325	33	65	98	130	163	195	228	260
	324	32	65	97	130	162	194	227	259
	323	32	65	97	129	162	[illegible]	226	258
	322	32	64	97	129	161	193	225	258
	321	32	64	96	128	161	193	225	257
	320	32	64	96	128	160	192	224	256
	319	32	64	96	128	160	191	223	255
	318	32	64	95	127	159	191	223	254
	317	32	63	95	127	159	190	222	254
	316	32	63	95	126	158	190	221	253
	315	32	63	95	126	158	189	221	252
	314	31	63	94	126	157	188	220	251
	313	31	63	94	125	157	188	219	250
	312	31	62	94	125	156	187	218	250
	311	31	62	93	124	156	187	218	249
	310	31	62	93	124	155	186	217	248
	309	31	62	93	124	155	185	216	247
	308	31	62	92	123	154	185	216	246
	307	31	61	92	123	154	184	215	246
	Diff.	1	2	3	4	5	6	7	8

N.	0	1	2	3	4	5	6	7	8	9	Diff.
40	146128	6438	6748	7058	7367	7676	7985	8294	8603	8911	309
41	9219	9527	9835	*0142	*0449	*0756	*1063	*1370	*1676	*1982	307
42	152288	2594	2900	3205	3510	3815	4120	4424	4728	5032	305
43	5336	5640	5943	6246	6549	6852	7154	7457	7759	8061	303
44	8362	8664	8965	9266	9567	9868	*0168	*0469	*0769	*1068	301
45	161368	1667	1967	2266	2564	2863	3161	3460	3758	4055	299
46	4353	4650	4947	5244	5541	5838	6134	6430	6726	7022	297
47	7317	7613	7908	8203	8497	8792	9086	9380	9674	9968	295
48	170262	0555	0848	1141	1434	1726	2019	2311	2603	2895	293
49	3186	3478	3769	4060	4351	4641	4932	5222	5512	5802	291
50	176091	6381	6670	6959	7248	7536	7825	8113	8401	8689	289
51	8977	9264	9552	9839	*0126	*0413	*0699	*0986	*1272	*1558	287
52	181844	2129	2415	2700	2985	3270	3555	3839	4123	4407	285
53	4691	4975	5259	5542	5825	6108	6391	6674	6956	7239	283
54	7521	7803	8084	8366	8647	8928	9209	9490	9771	*0051	281
55	190332	0612	0892	1171	1451	1730	2010	2289	2567	2846	279
56	3125	3403	3681	3959	4237	4514	4792	5069	5346	5623	278
57	5900	6176	6453	6729	7005	7281	7556	7832	8107	8382	276
58	8657	8932	9206	9481	9755	*0029	*0303	*0577	*0850	*1124	274
59	201397	1670	1943	2216	2488	2761	3033	3305	3577	3848	272

N.	Diff.	1	2	3	4	5	6	7	8	9	Diff.
	306	31	61	92	122	153	184	214	245	275	306
	305	31	61	92	122	153	183	214	244	275	305
	304	30	61	91	122	152	182	213	243	274	304
	303	30	61	91	121	152	182	212	242	273	303
	302	30	60	91	121	151	181	211	242	272	302
	301	30	60	90	120	151	181	211	241	271	301
	300	30	60	90	120	150	180	210	240	270	300
	299	30	60	90	120	150	179	209	239	269	299
	298	30	60	89	119	149	179	209	238	268	298
	297	30	59	89	119	149	178	208	238	267	[illegible]
	296	30	59	89	118	148	178	207	237	266	296
	295	30	59	89	118	148	177	207	236	266	295
	294	29	59	88	118	147	176	206	235	265	294
	293	29	59	88	117	147	176	205	234	264	[illegible]
	292	29	58	88	117	146	175	204	234	263	292
	291	29	58	87	116	146	175	204	233	262	291
	290	29	58	87	116	145	174	203	232	261	290
	289	29	58	87	116	145	173	202	231	260	289
	288	29	58	86	115	144	173	202	230	259	288
	287	29	57	86	115	144	172	201	230	258	287
	286	29	57	86	114	143	172	200	229	257	286
	285	29	57	86	114	143	171	200	228	257	285
	284	28	57	85	114	142	170	199	227	256	284
	283	28	57	85	113	142	170	198	226	255	283
	282	28	56	85	113	141	169	197	226	254	282
	281	28	56	84	112	141	169	197	225	253	281
	280	28	56	84	112	140	168	196	224	252	280
	79	28	56	84	112	140	167	195	223	251	279
	78	28	56	83	111	139	167	195	222	250	278
	77	28	55	83	111	139	166	194	222	249	277
	76	28	55	83	110	138	166	193	221	248	276
	5	28	55	83	110	138	165	193	220	248	275
	4	27	55	82	110	137	164	192	219	247	274
	3	27	55	82	109	137	164	191	218	246	273
	2	27	54	82	109	136	163	190	218	245	272
		27	54	81	108	136	163	190	217	244	271
		1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8
160	204120	4391	4663	4934	5204	5475	5746	6016	6286
161	6826	7096	7365	7634	7904	8173	8441	8710	8979
162	9515	9783	*0051	*0319	*0586	*0853	*1121	*1388	*1654
163	212188	2454	2720	2986	3252	3518	3783	4049	4314
164	4844	5109	5373	5638	5902	6166	6430	6694	6957
165	217484	7747	8010	8273	8536	8798	9060	9323	9585
166	220108	0370	0631	0892	1153	1414	1675	1936	2196
167	2716	2976	3236	3496	3755	4015	4274	4533	4792
168	5309	5568	5826	6084	6342	6600	6858	7115	7372
169	7887	8144	8400	8657	8913	9170	9426	9682	9938
170	230449	0704	0960	1215	1470	1724	1979	2234	2488
171	2996	3250	3504	3757	4011	4264	4517	4770	5023
172	5528	5781	6033	6285	6537	6789	7041	7292	7544
173	8046	8297	8548	8799	9049	9299	9550	9800	*0050
174	240549	0799	1048	1297	1546	1795	2044	2293	2541
175	243038	3286	3534	3782	4030	4277	4525	4772	5019
176	5513	5759	6006	6252	6499	6745	6991	7237	7482
177	7973	8219	8464	8709	8954	9198	9443	9687	9932
178	250420	0664	0908	1151	1395	1638	1881	2125	2368
179	2853	3096	3338	3580	3822	4064	4306	4548	4790

PROPORTIONAL PARTS

N	Diff	1	2	3	4	5	6	7	8
	272	27	54	82	109	136	163	190	218
	271	27	54	81	108	136	163	190	217
	270	27	54	81	108	135	162	189	216
	269	27	54	81	108	135	161	188	215
	268	27	54	80	107	134	161	188	214
	267	27	53	80	107	134	160	187	214
	266	27	53	80	106	133	160	186	213
	265	27	53	80	106	133	159	186	212
	264	26	53	79	106	132	158	185	211
	263	26	53	79	105	132	158	184	210
	262	26	52	79	105	131	157	183	210
	261	26	52	78	104	131	157	183	209
	260	26	52	78	104	130	156	182	208
	259	26	52	78	104	130	155	181	207
	258	26	52	77	103	129	155	181	206
	257	26	51	77	103	129	154	180	206
	256	26	51	77	102	128	154	179	205
	255	26	51	77	102	128	153	179	204
	254	25	51	76	102	127	152	178	203
	253	25	51	76	101	127	152	177	202
	252	25	50	76	101	126	151	176	202
	251	25	50	75	100	126	151	176	201
	250	25	50	75	100	125	150	175	200
	249	25	50	75	100	125	149	174	199
	248	25	50	74	99	124	149	174	198
	247	25	49	74	99	124	148	173	198
	246	25	49	74	98	123	148	172	197
	245	25	49	74	98	123	147	172	196
	244	24	49	73	98	122	146	171	195
	243	24	49	73	97	122	146	170	194
	242	24	48	73	97	121	145	169	194
	241	24	48	72	96	121	145	169	193
	240	24	48	72	96	120	144	168	192
	Diff.	1	2	3	4	5	6	7	8

0	1	2	3	4	5	6	7	8	9	Diff
255273	5514	5755	5996	6237	6477	6718	6958	7198	7439	241
7679	7918	8158	8398	8637	8877	9116	9355	9594	9833	239
260071	0310	0548	0787	1025	1263	1501	1739	1976	2214	238
2451	2688	2925	3162	3399	3636	3873	4109	4346	4582	237
4818	5054	5290	5525	5761	5996	6232	6467	6702	6937	235
267172	7406	7641	7875	8110	8344	8578	8812	9046	9279	234
9513	9746	9980	*0213	*0446	*0679	*0912	*1144	*1377	*1609	233
271842	2074	2306	2538	2770	3001	3233	3464	3696	3927	232
4158	4389	4620	4850	5081	5311	5542	5772	6002	6232	230
6462	6692	6921	7151	7380	7609	7838	8067	8296	8525	229
278754	8982	9211	9439	9667	9895	*0123	*0351	*0578	*0806	228
281033	1261	1488	1715	1942	2169	2396	2622	2849	3075	227
3301	3527	3753	3979	4205	4431	4656	4882	5107	5332	226
5557	5782	6007	6232	6456	6681	6905	7130	7354	7578	225
7802	8026	8249	8473	8696	8920	9143	9366	9589	9812	223
290035	0257	0480	0702	0925	1147	1369	1591	1813	2034	222
2256	2478	2699	2920	3141	3363	3584	3804	4025	4246	221
4466	4687	4907	5127	5347	5567	5787	6007	6226	6446	220
6665	6884	7104	7323	7542	7761	7979	8198	8416	8635	219
8853	9071	9289	9507	9725	9943	*0161	*0378	*0595	*0813	218
301030	1247	1464	1681	1898	2114	2331	2547	2764	2980	217
3196	3412	3628	3844	4059	4275	4491	4706	4921	5136	216
5351	5566	5781	5996	6211	6425	6639	6854	7068	7282	215
7496	7710	7924	8137	8351	8564	8778	8991	9204	9417	213
9630	9843	*0056	*0268	*0481	*0693	*0906	*1118	*1330	*1542	212

Diff.	1	2	3	4	5	6	7	8	9	Diff.
239	24	48	72	96	120	143	167	191	215	239
238	24	48	71	95	119	143	167	190	214	238
237	24	47	71	95	119	142	166	190	213	237
236	24	47	71	94	118	142	165	189	212	236
235	24	47	71	94	118	141	165	188	212	235
234	23	47	70	94	117	140	164	187	211	234
233	23	47	70	93	117	140	163	186	210	233
232	23	46	70	93	116	139	162	186	209	232
231	23	46	69	92	116	139	162	185	208	231
230	23	46	69	92	115	138	161	184	207	230
229	23	46	69	92	115	137	160	183	206	229
228	23	46	68	91	114	137	160	182	205	228
227	23	45	68	91	114	136	159	182	204	227
226	23	45	68	90	113	136	158	181	203	226
225	23	45	68	90	113	135	158	180	203	225
224	22	45	67	90	112	134	157	179	202	224
223	22	45	67	89	112	134	156	178	201	223
222	22	44	67	89	111	133	155	178	200	222
221	22	44	66	88	111	133	155	177	199	221
220	22	44	66	88	110	132	154	176	198	220
219	22	44	66	88	110	131	153	175	197	219
218	22	44	65	87	109	131	153	174	196	218
217	22	43	65	87	109	130	152	174	195	217
216	22	43	65	86	108	130	151	173	194	216
215	22	43	65	86	108	129	151	172	194	215
214	21	43	64	86	107	128	150	171	193	214
213	21	43	64	85	107	128	149	170	192	213
212	21	42	64	85	106	127	148	170	191	212
Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9
205	311754	1966	2177	2389	2600	2812	3023	3234	3445	3
206	3867	4078	4289	4499	4710	4920	5130	5340	5551	5
207	5970	6180	6390	6599	6809	7018	7227	7436	7646	7
208	8003	8272	8481	8689	8898	9106	9314	9522	9730	9
209	320146	0354	0562	0769	0977	1184	1391	1598	1805	2
210	322219	2426	2633	2839	3046	3252	3458	3665	3871	4
211	4282	4488	4694	4899	5105	5310	5516	5721	5926	6
212	6336	6541	6745	6950	7155	7359	7563	7767	7972	8
213	8380	8583	8787	8991	9194	9398	9601	9805	*0008	*0
214	330414	0617	0819	1022	1225	1427	1630	1832	2034	2
215	332438	2640	2842	3044	3246	3447	3649	3850	4051	4
216	4454	4655	4856	5057	5257	5458	5658	5859	6059	6
217	6460	6660	6860	7060	7260	7459	7659	7858	8058	8
218	8456	8656	8855	9054	9253	9451	9650	9849	*0047	*0
219	340444	0642	0841	1039	1237	1435	1632	1830	2028	2
220	342423	2620	2817	3014	3212	3409	3606	3802	3999	4
221	4392	4589	4785	4981	5178	5374	5570	5766	5962	6
222	6353	6549	6744	6939	7135	7330	7525	7720	7915	8
223	8305	8500	8694	8889	9083	9278	9472	9666	9860	*0
224	350248	0442	0636	0829	1023	1216	1410	1603	1796	1
225	352183	2375	2568	2761	2954	3147	3339	3532	3724	3
226	4108	4301	4493	4685	4876	5068	5260	5452	5643	5
227	6026	6217	6408	6599	6790	6981	7172	7363	7554	7
228	7935	8125	8316	8506	8696	8886	9076	9266	9456	9
229	9835	*0025	*0215	*0404	*0593	*0783	*0972	*1161	*1350	*1
230	361728	1917	2105	2294	2482	2671	2859	3048	3236	3
231	3612	3800	3988	4176	4363	4551	4739	4926	5113	5
232	5488	5675	5862	6049	6236	6423	6610	6796	6983	7
233	7356	7542	7729	7915	8101	8287	8473	8659	8845	9
234	9216	9401	9587	9772	9958	*0143	*0328	*0513	*0698	*0

N.	Diff.	1	2	3	4	5	6	7	8	9
PROPORTIONAL PARTS	212	21	42	64	85	106	127	148	170	
	211	21	42	63	84	106	127	148	169	
	210	21	42	63	84	105	126	147	168	
	209	21	42	63	84	105	125	146	167	
	208	21	42	62	83	104	125	146	166	
	207	21	41	62	83	104	124	145	166	1
	206	21	41	62	82	103	124	144	165	1
	205	21	41	62	82	103	123	144	164	1
	204	20	41	61	82	102	122	143	163	1
	203	20	41	61	81	102	122	142	162	1
	202	20	40	61	81	101	121	141	162	1
	201	20	40	60	80	101	121	141	161	1
	200	20	40	60	80	100	120	140	160	1
	199	20	40	60	80	100	119	139	159	1
	198	20	40	59	79	99	119	139	158	1
	197	20	39	59	79	99	118	138	158	1
	196	20	39	59	78	98	118	137	157	1
	195	20	39	59	78	98	117	137	156	1
	194	19	39	58	78	97	116	136	155	1
	193	19	39	58	77	97	116	135	154	1
	192	19	38	58	77	96	115	134	154	1
	191	19	38	57	76	96	115	134	153	1
	190	19	38	57	76	95	114	133	152	1
	189	19	38	57	76	95	113	132	151	1
	188	19	38	56	75	94	113	132	150	1
	Diff.	1	2	3	4	5	6	7	8	

N.	0	1	2	3	4	5	6	7	8	9	Dif.
235	371068	1253	1437	1622	1806	1991	2175	2360	2544	2728	184
236	2912	3096	3280	3464	3647	3831	4015	4198	4382	4565	184
237	4748	4932	5115	5298	5481	5664	5846	6029	6212	6395	183
238	6577	6759	6942	7124	7306	7488	7670	7852	8034	8216	182
239	8398	8580	8761	8943	9124	9306	9487	9668	9849	*0030	181
240	380211	0392	0573	0754	0934	1115	1296	1476	1656	1837	181
241	2017	2197	2377	2557	2737	2917	3097	3277	3456	3636	180
242	3815	3995	4174	4353	4533	4712	4891	5070	5249	5428	179
243	5606	5785	5964	6142	6321	6499	6677	6856	7034	7212	178
244	7390	7568	7746	7923	8101	8279	8456	8634	8811	8989	178
245	389166	9343	9520	9698	9875	*0051	*0228	*0405	*0582	*0759	177
246	390935	1112	1288	1464	1641	1817	1993	2169	2345	2521	176
247	2697	2873	3048	3224	3400	3575	3751	3926	4101	4277	176
248	4452	4627	4802	4977	5152	5326	5501	5676	5850	6025	175
249	6199	6374	6548	6722	6896	7071	7245	7419	7592	7766	174
250	397940	8114	8287	8461	8634	8808	8981	9154	9328	9501	173
251	9674	9847	*0020	*0192	*0365	*0538	*0711	*0883	*1056	*1228	173
252	401401	1573	1745	1917	2089	2261	2433	2605	2777	2949	172
253	3121	3292	3464	3635	3807	3978	4149	4320	4492	4663	171
254	4834	5005	5176	5346	5517	5688	5858	6029	6199	6370	171
255	406540	6710	6881	7051	7221	7391	7561	7731	7901	8070	170
256	8240	8410	8579	8749	8918	9087	9257	9426	9595	9764	169
257	9933	*0102	*0271	*0440	*0609	*0777	*0946	*1114	*1283	*1451	169
258	411620	1788	1956	2124	[illegible]	2461	2629	2796	2964	3132	168
259	3300	3467	3635	3803	3970	4137	4305	4472	4639	4806	167
260	414973	5140	5307	5474	5641	5808	5974	6141	6308	6474	167
261	6641	6807	6973	7139	7306	7472	7638	7804	7970	8135	166
262	8301	8467	8633	8798	8964	9129	9295	9460	9625	9791	165
263	9956	*0121	*0286	*0451	*0616	*0781	*0945	*1110	*1275	*1439	165
264	421604	1768	1933	2097	2261	2426	2590	2754	2918	3082	164

.	Dif.	1	2	3	4	5	6	7	8	9	Dif.
	187	19	37	56	75	94	112	131	150	168	187
	186	19	37	56	74	93	112	130	149	167	186
	185	19	37	56	74	93	111	130	148	167	185
	184	18	37	55	74	92	110	129	147	166	184
	183	[illegible]	37	55	73	92	110	128	146	165	183
	182	18	36	55	73	91	109	127	146	164	182
	181	18	36	54	[illegible]	91	109	127	145	163	181
	180	18	36	54	72	90	108	126	144	162	180
	179	18	36	54	72	90	107	125	143	161	179
	178	18	36	53	71	89	107	125	142	160	178
	177	18	35	53	71	89	106	124	142	159	177
	176	18	35	53	70	88	106	123	141	158	176
	175	18	35	53	70	88	105	123	140	158	[illegible]
	174	17	35	52	70	87	104	122	139	157	174
	173	17	35	52	69	87	104	121	138	156	173
	172	17	34	52	69	86	103	120	138	155	172
	171	17	34	51	68	86	103	120	137	154	171
	170	17	34	51	68	85	102	119	136	153	170
	169	17	34	51	68	85	101	118	135	152	169
	168	17	34	50	67	84	101	118	134	151	168
	167	17	33	50	67	84	100	117	134	150	167
	166	17	33	50	66	83	100	116	133	149	166
	165	17	33	50	66	83	99	116	132	149	165
	164	16	33	49	66	82	98	115	131	148	164
f.	1	2	3	[illegible]	5	6	7	8	9	Dif.	

N	0	1	2	3	4	5	6	7	8
265	423246	3410	3574	3737	3901	4065	4228	4392	4555
266	4882	5045	5208	5371	5534	5697	5860	6023	6186
267	6511	6674	6836	6999	7161	7324	7486	7648	7811
268	8135	8297	8459	8621	8783	8944	9106	9268	9429
269	9752	9914	*0075	*0236	*0398	*0559	*0720	*0881	*1042
270	431364	1525	1685	1846	2007	2167	2328	2488	2649
271	2969	3130	3290	3450	3610	3770	3930	4090	4249
272	4569	4729	4888	5048	5207	5367	5526	5685	5844
273	6163	6322	6481	6640	6799	6957	7116	7275	7433
274	7751	7909	8067	8226	8384	8542	8701	8859	9017
275	439333	9491	9648	9806	9964	*0122	*0279	*0437	*0594
276	440909	1066	1224	1381	1538	1695	1852	2009	2166
277	2480	2637	2793	2950	3106	3263	3419	3576	3732
278	4045	4201	4357	4513	4669	4825	4981	5137	5293
279	5604	5760	5915	6071	6226	6382	6537	6692	6848
280	447158	7313	7468	7623	7778	7933	8088	8242	8397
281	8706	8861	9015	9170	9324	9478	9633	9787	9941
282	450249	0403	0557	0711	0865	1018	1172	1326	1479
283	1786	1940	2093	2247	2400	2553	2706	2859	3012
284	3318	3471	3624	3777	3930	4082	4235	4387	4540
285	454845	4997	5150	5302	5454	5606	5758	5910	6062
286	6366	6518	6670	6821	6973	7125	7276	7428	7579
287	7882	8033	8184	8336	8487	8638	8789	8940	9091
288	9392	9543	9694	9845	9995	*0146	*0296	*0447	*0597
289	460898	1048	1198	1348	1499	1649	1799	1948	2098
290	462398	2548	2697	2847	2997	3146	3296	3445	3594
291	3893	4042	4191	4340	4490	4639	4788	4936	5085
292	5383	5532	5680	5829	5977	6126	6274	6423	6571
293	6868	7016	7164	7312	7460	7608	7756	7904	8052
294	8347	8495	8643	8790	8938	9085	9233	9380	9527
295	469822	9969	*0116	*0263	*0410	*0557	*0704	*0851	*0998
296	471292	1438	1585	1732	1878	2025	2171	2318	2464
297	2756	2903	3049	3195	3341	3487	3633	3779	3925
298	4216	4362	4508	4653	4799	4944	5090	5235	5381
299	5671	5816	5962	6107	6252	6397	6542	6687	6832

PROPORTIONAL PARTS

N.	Diff	1	2	3	4	5	6	7	8
	164	16	33	49	66	82	98	115	131
	163	16	33	49	65	82	98	114	130
	162	16	32	49	65	81	97	113	130
	161	16	32	48	64	81	97	113	129
	160	16	32	48	64	80	96	112	128
	159	16	32	48	64	80	95	111	127
	158	16	32	47	63	79	95	111	126
	157	16	31	47	63	79	94	110	126
	156	16	31	47	62	78	94	109	125
	155	16	31	47	62	78	93	109	124
	154	15	31	46	62	77	92	108	123
	153	15	31	46	61	77	92	107	122
	152	15	30	46	61	76	91	106	122
	151	15	30	45	60	76	91	106	121
	150	15	30	45	60	75	90	105	120
	149	15	30	45	60	75	89	104	119
	148	15	30	44	59	74	89	104	118
	147	15	29	44	59	74	88	103	118
	146	15	29	44	58	73	88	102	117
	145	15	29	44	58	73	87	102	116
	144	14	29	43	58	72	86	101	115
	143	14	29	43	57	72	86	100	114
	Diff.	1	2	3	4	5	6	7	8

0	1	2	3	4	5	6	7	8	9	Diff
477121	7266	7411	7555	7700	7844	7989	8133	8278	8422	145
8566	8711	8855	8999	9143	9287	9431	9575	9719	9863	144
480007	0151	0294	0438	0582	0725	0869	1012	1156	1299	144
1443	1586	1729	1872	2016	2159	2302	2445	2588	2731	143
2874	3016	3159	3302	3445	3587	3730	3872	4015	4157	143
484300	4442	4585	4727	4869	5011	5153	5295	5437	5579	142
5721	5863	6005	6147	6289	6430	6572	6714	6855	6997	142
7138	7280	7421	7563	7704	7845	7986	8127	8269	8410	141
8551	8692	8833	8974	9114	9255	9396	9537	9677	9818	141
9958	*0099	*0239	*0380	*0520	*0661	*0801	*0941	*1081	*1222	140
491362	1502	1642	1782	1922	2062	2201	2341	2481	2621	140
2760	2900	3040	3179	3319	3458	3597	3737	3876	4015	139
4155	4294	4433	4572	4711	4850	4989	5128	5267	5406	139
5544	5683	5822	5960	6099	6238	6376	6515	6653	6791	139
6930	7068	7206	7344	7483	7621	7759	7897	8035	8173	138
498311	8448	8586	8724	8862	8999	9137	9275	9412	9550	138
9687	9824	9962	*0099	*0236	*0374	*0511	*0648	*0785	*0922	137
501059	1196	1333	1470	1607	1744	1880	2017	2154	2291	137
2427	2564	2700	2837	2973	3109	3246	3382	3518	3655	136
3791	3927	4063	4199	4335	4471	4607	4743	4878	5014	136
505150	5286	5421	5557	5693	5828	5964	6099	6234	6370	136
6505	6640	6776	6911	7046	7181	7316	7451	7586	7721	135
7856	7991	8126	8260	8395	8530	8664	8799	8934	9068	135
9203	9337	9471	9606	9740	9874	*0009	*0143	*0277	*0411	134
510545	0679	0813	0947	1081	1215	1349	1482	1616	1750	134
511883	2017	2151	2284	2418	2551	2684	2818	2951	3084	133
3218	3351	3484	3617	3750	3883	4016	4149	4282	4415	133
4548	4681	4813	4946	5079	5211	5344	5476	5609	5741	133
5874	6006	6139	6271	6403	6535	6668	6800	6932	7064	132
7196	7328	7460	7592	7724	7855	7987	8119	8251	8382	132
518514	8646	8777	8909	9040	9171	9303	9434	9566	9697	131
9828	9959	*0090	*0221	*0353	*0484	*0615	*0745	*0876	*1007	131
521138	1269	1400	1530	1661	1792	1922	2053	2183	2314	131
2444	2575	2705	2835	2966	3096	3226	3356	3486	3616	130
3746	3876	4006	4136	4266	4396	4526	4656	4785	4915	130
525045	5174	5304	5434	5563	5693	5822	5951	6081	6210	129
6339	6469	6598	6727	6856	6985	7114	7243	7372	7501	129
7630	7759	7888	8016	8145	8274	8402	8531	8660	8788	129
8917	9045	9174	9302	9430	9559	9687	9815	9943	*0072	128
530200	0328	0456	0584	0712	0840	0968	1096	1223	1351	128

Diff.	1	2	3	4	5	6	7	8	9	Diff
142	14	28	43	57	71	85	99	114	128	142
141	14	28	42	56	71	85	99	113	127	141
140	14	28	42	56	70	84	98	112	126	140
139	14	28	42	56	70	83	97	111	125	139
138	14	28	41	55	69	83	97	110	124	138
137	14	27	41	55	69	82	96	110	123	137
136	14	27	41	54	68	82	95	109	122	136
135	14	27	41	54	68	81	95	108	122	135
134	13	27	40	54	67	80	94	107	121	134
133	13	27	40	53	67	80	93	106	120	133
132	13	26	40	53	66	79	92	106	119	132
131	13	26	39	52	66	79	92	105	118	131
130	13	26	39	52	65	78	91	104	117	130
129	13	26	39	52	65	77	90	103	116	129
128	13	26	38	51	64	77	90	102	115	128
127	13	25	38	51	64	76	89	102	114	127
Diff.	1	2	3	4	5	6	7	8	9	Diff

N.	0	1	2	3	4	5	6	7	8
340	531479	1607	1734	1862	1990	2117	2245	2372	2500
341	2754	2882	3009	3136	3264	3391	3518	3645	3772
342	4026	4153	4280	4407	4534	4661	4787	4914	5041
343	5294	5421	5547	5674	5800	5927	6053	6180	6306
344	6558	6685	6811	6937	7063	7189	7315	7441	7567
345	537819	7945	8071	8197	8322	8448	8574	8699	8825
346	9076	9202	9327	9452	9578	9703	9829	9954	*0079
347	540329	0455	0580	0705	0830	0955	1080	1205	1330
348	1579	1704	1829	1953	2078	2203	2327	2452	2576
349	2825	2950	3074	3199	3323	3447	3571	3696	3820
350	544068	4192	4316	4440	4564	4688	4812	4936	5060
351	5307	5431	5555	5678	5802	5925	6049	6172	6296
352	6543	6666	6789	6913	7036	7159	7282	7405	7529
353	7775	7898	8021	8144	8267	8389	8512	8635	8758
354	9003	9126	9249	9371	9494	9616	9739	9861	9984
355	550228	0351	0473	0595	0717	0840	0962	1084	1206
356	1450	1572	1694	1816	1938	2060	2181	2303	2425
357	2668	2790	2911	3033	3155	3276	3398	3519	3640
358	3883	4004	4126	4247	4368	4489	4610	4731	4852
359	5094	5215	5336	5457	5578	5699	5820	5940	6061
360	556303	6423	6544	6664	6785	6905	7026	7146	7267
361	7507	7627	7748	7868	7988	8108	8228	8349	8469
362	8709	8829	8948	9068	9188	9308	9428	9548	9667
363	9907	*0026	*0146	*0265	*0385	*0504	*0624	*0743	*0863
364	561101	1221	1340	1459	1578	1698	1817	1936	2055
365	562293	2412	2531	2650	2769	2887	3006	3125	3244
366	3481	3600	3718	3837	3955	4074	4192	4311	4429
367	4666	4784	4903	5021	5139	5257	5376	5494	5612
368	5848	5966	6084	6202	6320	6437	6555	6673	6791
369	7026	7144	7262	7379	7497	7614	7732	7849	7967
370	568202	8319	8436	8554	8671	8788	8905	9023	9140
371	9374	9491	9608	9725	9842	9959	*0076	*0193	*0309
372	570543	0660	0776	0893	1010	1126	1243	1359	1476
373	1709	1825	1942	2058	2174	2291	2407	2523	2639
374	2872	2988	3104	3220	3336	3452	3568	3684	3800
375	574031	4147	4263	4379	4494	4610	4726	4841	4957
376	5188	5303	5419	5534	5650	5765	5880	5996	6111
377	6341	6457	6572	6687	6802	6917	7032	7147	7262
378	7492	7607	7722	7836	7951	8066	8181	8295	8410
379	8639	8754	8868	8983	9097	9212	9326	9441	9555

N.	Diff.	1	2	3	4	5	6	7	8
PROP. PARTS	128	13	26	38	51	64	77	90	102
	127	13	25	38	51	64	76	89	102
	126	13	25	38	50	63	76	88	101
	125	13	25	38	50	63	75	88	100
	124	12	25	37	50	62	74	87	99
	123	12	25	37	49	62	74	86	98
	122	12	24	37	49	61	73	85	98
	121	12	24	36	48	61	73	85	97
	120	12	24	36	48	60	72	84	96
	119	12	24	36	48	60	71	83	95
	118	12	24	35	47	59	71	83	94
	117	12	23	35	47	59	70	82	94
	116	12	23	35	46	58	70	81	93
	Diff	1	2	3	4	5	6	7	8

[redacted]

0	1	2	[illegible]	4	5	6	7	8	[illegible]	Diff.
579784	9898	*0012	*0126	*0241	*0355	*0469	*0583	*0697	*0811	114
580925	1039	1153	1267	1381	1495	1608	1722	1836	1950	114
2063	2177	2291	2404	2518	2631	2745	2858	2972	3085	114
3199	3312	3426	3539	3652	3765	3879	3992	4105	4218	113
4331	4444	4557	4670	4783	4896	5009	5122	5235	5348	113
585461	5574	5686	5799	5912	6024	6137	6250	6362	6475	113
6587	6700	6812	6925	7037	7149	7262	7374	7486	7599	112
7711	7823	7935	8047	8160	8272	8384	8496	8608	8720	112
8832	8944	9056	9167	9279	9391	9503	9615	9726	9838	112
9950	*0061	*0173	*0284	*0396	*0507	*0619	*0730	*0842	*0953	112
591065	1176	1287	1399	1510	1621	1732	1843	1955	2066	111
2177	2288	2399	2510	2621	2732	2843	2954	3064	3175	111
3286	3397	3508	3618	3729	3840	3950	4061	4171	4282	111
4393	4503	4614	4724	4834	4945	5055	5165	5276	5386	110
5496	5606	5717	5827	5937	6047	6157	6267	6377	6487	110
596597	6707	6817	6927	7037	7146	7256	7366	7476	7586	110
7695	7805	7914	8024	8134	8243	8353	8462	8572	8681	110
8791	8900	9009	9119	9228	9337	9446	9556	9665	9774	109
9883	9992	*0101	*0210	*0319	*0428	*0537	*0646	*0755	*0864	109
600973	1082	1191	1299	1408	1517	1625	1734	1843	1951	109
602060	2169	2277	2386	2494	2603	2711	2819	2928	3036	108
3144	3253	3361	3469	3577	3686	3794	3902	4010	4118	108
4226	4334	4442	4550	4658	4766	4874	4982	5089	5197	108
5305	5413	5521	5628	5736	5844	5951	6059	6166	6274	108
6381	6489	6596	6704	6811	6919	7026	7133	7241	7348	107
607455	7562	7669	7777	7884	7991	8098	8205	8312	8419	107
8526	8633	8740	8847	8954	9061	9167	9274	9381	9488	107
9594	9701	9808	9914	*0021	*0128	*0234	*0341	*0447	*0554	107
610660	0767	0873	0979	1086	1192	1298	1405	1511	1617	106
1723	1829	1936	2042	2148	2254	2360	2466	2572	2678	106
612784	2890	2996	3102	3207	3313	3419	3525	3630	3736	106
3842	3947	4053	4159	4264	4370	4475	4581	4686	4792	106
4897	5003	5108	5213	5319	5424	5529	5634	5740	5845	105
5950	6055	6160	6265	6370	6476	6581	6686	6790	6895	105
7000	7105	7210	7315	7420	7525	7629	7734	7839	7943	105
618048	8153	8257	8362	8466	8571	8676	8780	8884	8989	105
9093	9198	9302	9406	9511	9615	9719	9824	9928	*0032	104
620136	0240	0344	0448	0552	0656	0760	0864	0968	1072	104
1176	1280	1384	1488	1592	1695	1799	1903	2007	2110	104
2214	2318	2421	2525	2628	2732	2835	2939	3042	3146	104

Diff.	1	2	3	4	5	6	7	8	[illegible]	Diff.
115	12	23	35	46	58	69	81	92	104	115
114	11	23	34	46	57	68	80	91	103	114
113	11	23	34	45	57	68	79	90	102	113
112	11	22	34	45	56	67	78	90	101	112
111	11	22	33	44	56	67	78	89	100	111
110	11	22	33	44	55	66	77	88	99	110
109	11	22	33	44	55	65	76	87	98	109
108	11	22	32	43	54	65	76	86	97	108
107	11	21	32	43	54	64	75	86	96	107
106	11	21	32	42	53	64	74	85	95	106
105	11	21	32	42	53	63	74	84	95	105
104	10	21	31	42	52	62	73	83	94	104
103	10	21	31	41	52	61	72	82	93	103
Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9	Di
420	623249	3353	3456	3559	3663	3766	3869	3973	4076	4179	10
421	4282	4385	4488	4591	4695	4798	4901	5004	5107	5210	10
422	5312	5415	5518	5621	5724	5827	5929	6032	6135	6238	10
423	6340	6443	6546	6648	6751	6853	6956	7058	7161	7263	10
424	7366	7468	7571	7673	7775	7878	7980	8082	8185	8287	10
425	628389	8491	8593	8695	8797	8900	9002	9104	9206	9308	10
426	9410	9512	9613	9715	9817	9919	*0021	*0123	*0224	*0326	10
427	630428	0530	0631	0733	0835	0936	1038	1139	1241	1342	10
428	1444	1545	1647	1748	1849	1951	2052	2153	2255	2356	10
429	2457	2559	2660	2761	2862	2963	3064	3165	3266	3367	10
430	633468	3569	3670	3771	3872	3973	4074	4175	4276	4376	10
431	4477	4578	4679	4779	4880	4981	5081	5182	5283	5383	10
432	5484	5584	5685	5785	5886	5986	6087	6187	6287	6388	10
433	6488	6588	6688	6789	6889	6989	7089	7189	7290	7390	10
434	7490	7590	7690	7790	7890	7990	8090	8190	8290	8389	10
435	638489	8589	8689	8789	8888	8988	9088	9188	9287	9387	10
436	9486	9586	9686	9785	9885	9984	*0084	*0183	*0283	*0382	9
437	640481	0581	0680	0779	0879	0978	1077	1177	1276	1375	9
438	1474	1573	1672	1771	1871	1970	2069	2168	2267	2366	9
439	2465	2563	2662	2761	2860	2959	3058	3156	3255	3354	9
440	643453	3551	3650	3749	3847	3946	4044	4143	4242	4340	9
441	4439	4537	4636	4734	4832	4931	5029	5127	5226	5324	9
442	5422	5521	5619	5717	5815	5913	6011	6110	6208	6306	9
443	6404	6502	6600	6698	6796	6894	6992	7089	7187	7285	9
444	7383	7481	7579	7676	7774	7872	7969	8067	8165	8262	9
445	648360	8458	8555	8653	8750	8848	8945	9043	9140	9237	9
446	9335	9432	9530	9627	9724	9821	9919	*0016	*0113	*0210	9
447	650308	0405	0502	0599	0696	0793	0890	0987	1084	1181	9
448	1278	1375	1472	1569	1666	1762	1859	1956	2053	2150	9
449	2246	2343	2440	2536	2633	2730	2826	2923	3019	3116	9
450	653213	3309	3405	3502	3598	3695	3791	3888	3984	4080	9
451	4177	4273	4369	4465	4562	4658	4754	4850	4946	5042	9
452	5138	5235	5331	5427	5523	5619	5715	5810	5906	6002	9
453	6098	6194	6290	6386	6482	6577	6673	6769	6864	6960	9
454	7056	7152	7247	7343	7438	7534	7629	7725	7820	7916	9
455	658011	8107	8202	8298	8393	8488	8584	8679	8774	8870	9
456	8965	9060	9155	9250	9346	9441	9536	9631	9726	9821	9
457	9916	*0011	*0106	*0201	*0296	*0391	*0486	*0581	*0676	*0771	9
458	660865	0960	1055	1150	1245	1339	1434	1529	1623	1718	9
459	1813	1907	2002	2096	2191	2286	2380	2475	2569	2663	9
460	662758	2852	2947	3041	3135	3230	3324	3418	3512	3607	9
461	3701	3795	3889	3983	4078	4172	4266	4360	4454	4548	9
462	4642	4736	4830	4924	5018	5112	5206	5299	5393	5487	9
463	5581	5675	5769	5862	5956	6050	6143	6237	6331	6424	9
464	6518	6612	6705	6799	6892	6986	7079	7173	7266	7360	9

N	Diff.	1	2	3	4	5	6	7	8	9
PROP. PARTS	104	10	21	31	42	52	62	73	83	94
	103	10	21	31	41	52	62	72	82	93
	102	10	20	31	41	51	61	71	82	92
	101	10	20	30	40	51	61	71	81	91
	100	10	20	30	40	50	60	70	80	90
	99	10	20	30	40	50	59	69	79	89
	98	10	20	29	39	49	59	69	78	88
	97	10	19	29	39	49	58	68	78	87
	96	10	19	29	38	48	58	67	77	86
	95	10	19	29	38	48	57	67	76	86
	Diff.	1	2	3	4	5	6	7	8	9

0	1	2	3	4	5	6	7	8	9	Diff.
667453	7546	7640	7733	7826	7920	8013	8106	8199	8293	93
8386	8479	8572	8665	8759	8852	8945	9038	9131	9224	93
9317	9410	9503	9596	9689	9782	9875	9967	*0060	*0153	93
670246	0339	0431	0524	0617	0710	0802	0895	0988	1080	93
1173	1265	1358	1451	1543	1636	1728	1821	1913	2005	93
672098	2190	2283	2375	2467	2560	2652	2744	2836	2929	92
3021	3113	3205	3297	3390	3482	3574	3666	3758	3850	92
3942	4034	4126	4218	4310	4402	4494	4586	4677	4769	92
4861	4953	5045	5137	5228	5320	5412	5503	5595	5687	92
5778	5870	5962	6053	6145	6236	6328	6419	6511	6602	92
676694	6785	6876	6968	7059	7151	7242	7333	7424	7516	91
7607	7698	7789	7881	7972	8063	8154	8245	8336	8427	91
8518	8609	8700	8791	8882	8973	9064	9155	9246	9337	91
9428	9519	9610	9700	9791	9882	9973	*0063	*0154	*0245	91
680336	0426	0517	0607	0698	0789	0879	0970	1060	1151	91
681241	1332	1422	1513	1603	1693	1784	1874	1964	2055	90
2145	2235	2326	2416	2506	2596	2686	2777	2867	2957	90
3047	3137	3227	3317	3407	3497	3587	3677	3767	3857	90
3947	4037	4127	4217	4307	4396	4486	4576	4666	4756	90
4845	4935	5025	5114	5204	5294	5383	5473	5563	5652	90
685742	5831	5921	6010	6100	6189	6279	6368	6458	6547	89
6636	6726	6815	6904	6994	7083	7172	7261	7351	7440	89
7529	7618	7707	7796	7886	7975	8064	8153	8242	8331	89
8420	8509	8598	8687	8776	8865	8953	9042	9131	9220	89
9309	9398	9486	9575	9664	9753	9841	9930	*0019	*0107	89
690196	0285	0373	0462	0550	0639	0728	0816	0905	0993	89
1081	1170	1258	1347	1435	1524	1612	1700	1789	1877	88
1965	2053	2142	2230	2318	2406	2494	2583	2671	2759	88
2847	2935	3023	3111	3199	3287	3375	3463	3551	3639	88
3727	3815	3903	3991	4078	4166	4254	4342	4430	4517	88
694605	4693	4781	4868	4956	5044	5131	5219	5307	5394	88
5482	5569	5657	5744	5832	5919	6007	6094	6182	6269	87
6356	6444	6531	6618	6706	6793	6880	6968	7055	7142	87
7229	7317	7404	7491	7578	7665	7752	7839	7926	8014	87
8101	8188	8275	8362	8449	8535	8622	8709	8796	8883	87
698970	9057	9144	9231	9317	9404	9491	9578	9664	9751	87
9838	9924	*0011	*0098	*0184	*0271	*0358	*0444	*0531	*0617	87
700704	0790	0877	0963	1050	1136	1222	1309	1395	1482	86
1568	1654	1741	1827	1913	1999	2086	2172	2258	2344	86
2431	2517	2603	2689	2775	2861	2947	3033	3119	3205	86
703291	3377	3463	3549	3635	3721	3807	3893	3979	4065	86
4151	4236	4322	4408	4494	4579	4665	4751	4837	4922	86
5008	5094	5179	5265	5350	5436	5522	5607	5693	5778	86
5864	5949	6035	6120	6206	6291	6376	6462	6547	6632	85
6718	6803	6888	6974	7059	7144	7229	7315	7400	7485	85

Diff.	1	2	3	4	5	6	7	8	9	Diff
94	9	19	28	38	47	56	66	75	85	**94**
93	9	19	28	37	47	56	65	74	84	**93**
92	9	18	28	37	46	55	64	74	83	**92**
91	9	18	27	36	46	55	64	73	82	**91**
90	9	18	27	36	45	54	63	72	81	**90**
89	9	18	27	36	45	53	62	71	80	**89**
88	9	18	26	35	44	53	62	70	79	**88**
87	9	17	26	35	44	52	61	70	78	**87**
86	9	17	26	34	43	52	60	69	77	**86**
85	9	17	26	34	43	51	60	68	77	**85**

Diff. 1 2 3 4 5 6 7 8 9 Diff

N	0	1	2	3	4	5	6	7	8
510	707570	7655	7740	7826	7911	7996	8081	8166	8251
511	8421	8506	8591	8676	8761	8846	8931	9015	9100
512	9270	9355	9440	9524	9609	9694	9779	9863	9948
513	710117	0202	0287	0371	0456	0540	0625	0710	0794
514	0963	1048	1132	1217	1301	1385	1470	1554	1639
515	711807	1892	1976	2060	2144	2229	2313	2397	2481
516	2650	2734	2818	2902	2986	3070	3154	3238	3323
517	3491	3575	3659	3742	3826	3910	3994	4078	4162
518	4330	4414	4497	4581	4665	4749	4833	4916	5000
519	5167	5251	5335	5418	5502	5586	5669	5753	5836
520	716003	6087	6170	6254	6337	6421	6504	6588	6671
521	6838	6921	7004	7088	7171	7254	7338	7421	7504
522	7671	7754	7837	7920	8003	8086	8169	8253	8336
523	8502	8585	8668	8751	8834	8917	9000	9083	9165
524	9331	9414	9497	9580	9663	9745	9828	9911	9994
525	720159	0242	0325	0407	0490	0573	0655	0738	0821
526	0986	1068	1151	1233	1316	1398	1481	1563	1646
527	1811	1893	1975	2058	2140	2222	2305	2387	2469
528	2634	2716	2798	2881	2963	3045	3127	3209	3291
529	3456	3538	3620	3702	3784	3866	3948	4030	4112
530	724276	4358	4440	4522	4604	4685	4767	4849	4931
531	5095	5176	5258	5340	5422	5503	5585	5667	5748
532	5912	5993	6075	6156	6238	6320	6401	6483	6564
533	6727	6809	6890	6972	7053	7134	7216	7297	7379
534	7541	7623	7704	7785	7866	7948	8029	8110	8191
535	728354	8435	8516	8597	8678	8759	8841	8922	9003
536	9165	9246	9327	9408	9489	9570	9651	9732	9813
537	9974	*0055	*0136	*0217	*0298	*0378	*0459	*0540	*0621
538	730782	0863	0944	1024	1105	1186	1266	1347	1428
539	1589	1669	1750	1830	1911	1991	2072	2152	2233
540	732394	2474	2555	2635	2715	2796	2876	2956	3037
541	3197	3278	3358	3438	3518	3598	3679	3759	3839
542	3999	4079	4160	4240	4320	4400	4480	4560	4640
543	4800	4880	4960	5040	5120	5200	5279	5359	5439
544	5599	5679	5759	5838	5918	5998	6078	6157	6237
545	736397	6476	6556	6635	6715	6795	6874	6954	7034
546	7193	7272	7352	7431	7511	7590	7670	7749	7829
547	7987	8067	8146	8225	8305	8384	8463	8543	8622
548	8781	8860	8939	9018	9097	9177	9256	9335	9414
549	9572	9651	9731	9810	9889	9968	*0047	*0126	*0205
550	740363	0442	0521	0600	0678	0757	0836	0915	0994
551	1152	1230	1309	1388	1467	1546	1624	1703	1782
552	1939	2018	2096	2175	2254	2332	2411	2489	2568
553	2725	2804	2882	2961	3039	3118	3196	3275	3353
554	3510	3588	3667	3745	3823	3902	3980	4058	4136
N	Diff	1	2	3	4	5	6	7	8

PROP. PARTS

Diff.	1	2	3	4	5	6	7	8
86	9	17	26	34	43	52	60	69
85	9	17	26	34	43	51	60	68
84	8	17	25	34	42	50	59	67
83	8	17	25	33	42	50	58	66
82	8	16	25	33	41	49	57	66
81	8	16	24	32	41	49	57	65
80	8	16	24	32	40	48	56	64
79	8	16	24	32	40	47	55	63

	0	1	2	3	4	5	6	7	8	9	Diff
5	744293	4371	4449	4528	4606	4684	4762	4840	4919	4997	78
6	5075	5153	5231	5309	5387	5465	5543	5621	5699	5777	78
7	5855	5933	6011	6089	6167	6245	6323	6401	6479	6556	78
8	6634	6712	6790	6868	6945	7023	7101	7179	7256	7334	78
9	7412	7489	7567	7645	7722	7800	7878	7955	8033	8110	78
0	748188	8266	8343	8421	8498	8576	8653	8731	8808	8885	77
1	8963	9040	9118	9195	9272	9350	9427	9504	9582	9659	77
2	9736	9814	9891	9968	*0045	*0123	*0200	*0277	*0354	*0431	77
3	750508	0586	0663	0740	0817	0894	0971	1048	1125	1202	77
4	1279	1356	1433	1510	1587	1664	1741	1818	1895	1972	77
5	752048	2125	2202	2279	2356	2433	2509	2586	2663	2740	77
6	2816	2893	2970	3047	3123	3200	3277	3353	3430	3506	77
7	3583	3660	3736	3813	3889	3966	4042	4119	4195	4272	77
8	4348	4425	4501	4578	4654	4730	4807	4883	4960	5036	76
9	5112	5189	5265	5341	5417	5494	5570	5646	5722	5799	76
0	755875	5951	6027	6103	6180	6256	6332	6408	6484	6560	76
1	6636	6712	6788	6864	6940	7016	7092	7168	7244	7320	76
2	7396	7472	7548	7624	7700	7775	7851	7927	8003	8079	76
3	8155	8230	8306	8382	8458	8533	8609	8685	8761	8836	76
4	8912	8988	9063	9139	9214	9290	9366	9441	9517	9592	76
5	759668	9743	9819	9894	9970	*0045	*0121	*0196	*0272	*0347	75
6	760422	0498	0573	0649	0724	0799	0875	0950	1025	1101	75
7	1176	1251	1326	1402	1477	1552	1627	1702	1778	1853	75
8	1928	2003	2078	2153	2228	2303	2378	2453	2529	2604	75
9	2679	2754	2829	2904	2978	3053	3128	3203	3278	3353	75
	763428	3503	3578	3653	3727	3802	3877	3952	4027	4101	75
	4176	4251	4326	4400	4475	4550	4624	4699	4774	4848	75
	4923	4998	5072	5147	5221	5296	5370	5445	5520	5594	75
	5669	5743	5818	5892	5966	6041	6115	6190	6264	6338	74
	6413	6487	6562	6636	6710	6785	6859	6933	7007	7082	74
	767156	7230	7304	7379	7453	7527	7601	7675	7749	7823	74
	7898	7972	8046	8120	8194	8268	8342	8416	8490	8564	74
	8638	8712	8786	8860	8934	9008	9082	9156	9230	9303	74
	9377	9451	9525	9599	9673	9746	9820	9894	9968	*0042	74
	770115	0189	0263	0336	0410	0484	0557	0631	0705	0778	74
	770852	0926	0999	1073	1146	1220	1293	1367	1440	1514	74
	1587	1661	1734	1808	1881	1955	2028	2102	2175	2248	73
	2322	2395	2468	2542	2615	2688	2762	2835	2908	2981	73
	3055	3128	3201	3274	3348	3421	3494	3567	3640	3713	73
	3786	3860	3933	4006	4079	4152	4225	4298	4371	4444	73
	774517	4590	4663	4736	4809	4882	4955	5028	5100	5173	73
	5246	5319	5392	5465	5538	5610	5683	5756	5829	5902	73
	5974	6047	6120	6193	6265	6338	6411	6483	6556	6629	73
	6701	6774	6846	6919	6992	7064	7137	7209	7282	7354	73
	7427	7499	7572	7644	7717	7789	7862	7934	8006	8079	72

Diff.	1	2	3	4	5	6	7	8	9	Diff.
78	8	16	23	31	39	47	55	62	70	78
77	8	15	23	31	39	46	54	62	69	77
76	8	15	23	30	38	46	53	61	68	76
75	8	15	23	30	38	45	53	60	68	75
74	7	15	22	30	37	44	52	59	67	74
73	7	15	22	29	37	44	51	58	66	73
72	7	14	22	29	36	43	50	58	65	72

1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8
600	778151	8224	8296	8368	8441	8513	8585	8658	8730
601	8874	8947	9019	9091	9163	9236	9308	9380	9452
602	9596	9669	9741	9813	9885	9957	*0029	*0101	*0173
603	780317	0389	0461	0533	0605	0677	0749	0821	0893
604	1037	1109	1181	1253	1324	1396	1468	1540	1612
605	781755	1827	1899	1971	2042	2114	2186	2258	2329
606	2473	2544	2616	2688	2759	2831	2902	2974	3046
607	3189	3260	3332	3403	3475	3546	3618	3689	3761
608	3904	3975	4046	4118	4189	4261	4332	4403	4475
609	4617	4689	4760	4831	4902	4974	5045	5116	5187
610	785330	5401	5472	5543	5615	5686	5757	5828	5899
611	6041	6112	6183	6254	6325	6396	6467	6538	6609
612	6751	6822	6893	6964	7035	7106	7177	7248	7319
613	7460	7531	7602	7673	7744	7815	7885	7956	8027
614	8168	8239	8310	8381	8451	8522	8593	8663	8734
615	788875	8946	9016	9087	9157	9228	9299	9369	9440
616	9581	9651	9722	9792	9863	9933	*0004	*0074	*0144
617	790285	0356	0426	0496	0567	0637	0707	0778	0848
618	0988	1059	1129	1199	1269	1340	1410	1480	1550
619	1691	1761	1831	1901	1971	2041	2111	2181	2252
620	792392	2462	2532	2602	2672	2742	2812	2882	2952
621	3092	3162	3231	3301	3371	3441	3511	3581	3651
622	3790	3860	3930	4000	4270	4139	4209	4279	4349
623	4488	4558	4627	4697	4767	4836	4906	4976	5045
624	5185	5254	5324	5393	5463	5532	5602	5672	5741
625	795880	5949	6019	6088	6158	6227	6297	6366	6436
626	6574	6644	6713	6782	6852	6921	6990	7060	7129
627	7268	7337	7406	7475	7545	7614	7683	7752	7821
628	7960	8029	8098	8167	8236	8305	8374	8443	8513
629	8651	8720	8789	8858	8927	8996	9065	9134	9203
630	799341	9409	9478	9547	9616	9685	9754	9823	9892
631	800029	0098	0167	0236	0305	0373	0442	0511	0580
632	0717	0786	0854	0923	0992	1061	1129	1198	1266
633	1404	1472	1541	1609	1678	1747	1815	1884	1952
634	2089	2158	2226	2295	2363	2432	2500	2568	2637
635	802774	2842	2910	2979	3047	3116	3184	3252	3321
636	3457	3525	3594	3662	3730	3798	3867	3935	4003
637	4139	4208	4276	4344	4412	4480	4548	4616	4685
638	4821	4889	4957	5025	5093	5161	5229	5297	5365
639	5501	5569	5637	5705	5773	5841	5908	5976	6044
640	806180	6248	6316	6384	6451	6519	6587	6655	6723
641	6858	6926	6994	7061	7129	7197	7264	7332	7400
642	7535	7603	7670	7738	7806	7873	7941	8008	8076
643	8211	8279	8346	8414	8481	8549	8616	8684	8751
644	8886	8953	9021	9088	9156	9223	9290	9358	9425
645	809560	9627	9694	9762	9829	9896	9964	*0031	*0098
646	810233	0300	0367	0434	0501	0569	0636	0703	0770
647	0904	0971	1039	1106	1173	1240	1307	1374	1441
648	1575	1642	1709	1776	1843	1910	1977	2044	2111
649	2245	2312	2379	2445	2512	2579	2646	2713	2780
N	Diff	1	2	3	4	5	6	7	8

PRO. P'TS	Diff.	1	2	3	4	5	6	7	8
	73	7	15	22	29	37	44	51	58
	72	7	14	22	29	36	43	50	58
	71	7	14	21	28	36	43	50	57
	70	7	14	21	28	35	42	49	56
	69	7	14	21	28	35	41	48	55
	68	7	14	20	27	34	41	48	54

.	0	1	2	3	4	5	6	7	8	9	Di
0	812913	2980	3047	3114	3181	3247	3314	3381	3448	3514	67
1	3581	3648	3714	3781	3848	3914	3981	4048	4114	4181	67
2	4248	4314	4381	4447	4514	4581	4647	4714	4780	4847	67
3	4913	4980	5046	5113	5179	5246	5312	5378	5445	5511	66
4	5578	5644	5711	5777	5843	5910	5976	6042	6109	6175	66
5	816241	6308	6374	6440	6506	6573	6639	6705	6771	6838	66
6	6904	6970	7036	7102	7169	7235	7301	7367	7433	7499	66
7	7565	7631	7698	7764	7830	7896	7962	8028	8094	8160	66
8	8226	8292	8358	8424	8490	8556	8622	8688	8754	8820	66
9	8885	8951	9017	9083	9149	9215	9281	9346	9412	9478	66
0	819544	9610	9676	9741	9807	9873	9939	*0004	*0070	*0136	66
1	820201	0267	0333	0399	0464	0530	0595	0661	0727	0792	66
2	0858	0924	0989	1055	1120	1186	1251	1317	1382	1448	66
3	1514	1579	1645	1710	1775	1841	1906	1972	2037	2103	65
4	2168	2233	2299	2364	2430	2495	2560	2626	2691	2756	65
5	822822	2887	2952	3018	3083	3148	3213	3279	3344	3409	65
6	3474	3539	3605	3670	3735	3800	3865	3930	3996	4061	65
7	4126	4191	4256	4321	4386	4451	4516	4581	4646	4711	65
8	4776	4841	4906	4971	5036	5101	5166	5231	5296	5361	65
9	5426	5491	5556	5621	5686	5751	5815	5880	5945	6010	65
0	826075	6140	6204	6269	6334	6399	6464	6528	6593	6658	65
1	6723	6787	6852	6917	6981	7046	7111	7175	7240	7305	65
2	7369	7434	7499	7563	7628	7692	7757	7821	7886	7951	65
3	8015	8080	8144	8209	8273	8338	8402	8467	8531	8595	64
4	8660	8724	8789	8853	8918	8982	9046	9111	9175	9239	64
5	829304	9368	9432	9497	9561	9625	9690	9754	9818	9882	64
	9947	*0011	*0075	*0139	*0204	*0268	*0332	*0396	*0460	*0525	64
	830589	0653	0717	0781	0845	0909	0973	1037	1102	1166	64
	1230	1294	1358	1422	1486	1550	1614	1678	1742	1806	64
	1870	1934	1998	2062	2126	2189	2253	2317	2381	2445	64
	832509	2573	2637	2700	2764	2828	2892	2956	3020	3083	64
	3147	3211	3275	3338	3402	3466	3530	3593	3657	3721	64
	3784	3848	3912	3975	4039	4103	4166	4230	4294	4357	64
	4421	4484	4548	4611	4675	4739	4802	4866	4929	4993	64
	5056	5120	5183	5247	5310	5373	5437	5500	5564	5627	63
	835691	5754	5817	5881	5944	6007	6071	6134	6197	6261	63
	6324	6387	6451	6514	6577	6641	6704	6767	6830	6894	63
	6957	7020	7083	7146	7210	7273	7336	7399	7462	7525	63
	7588	7652	7715	7778	7841	7904	7967	8030	8093	8156	63
	8219	8282	8345	8408	8471	8534	8597	8660	8723	8786	63
	38849	8912	8975	9038	9101	9164	9227	9289	9352	9415	63
	9478	9541	9604	9667	9729	9792	9855	9918	9981	*0043	63
	10106	0169	0232	0294	0357	0420	0482	0545	0608	0671	63
	0733	0796	0859	0921	0984	1046	1109	1172	1234	1297	63
	1359	1422	1485	1547	1610	1672	1735	1797	1860	1922	63
	1985	2047	2110	2172	2235	2297	2360	2422	2484	2547	62
	609	2672	2734	2796	2859	2921	2983	3046	3108	3170	62
	233	3295	3357	3420	3482	3544	3606	3669	3731	3793	62
	855	3918	3980	4042	4104	4166	4229	4291	4353	4415	62
	477	4539	4601	4664	4726	4788	4850	4912	[illegible]	5036	62

f.	1	2	3	4	5	6	7	8	9	Diff.
	7	13	20	27	34	40	47	54	60	67
	7	13	20	26	33	40	46	53	59	66
	7	13	20	26	33	39	46	52	59	65
	6	13	19	26	32	38	45	51	58	64
	6	13	19	25	32	38	44	50	57	63
	6	12	19	25	31	37	43	50	56	62
	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8
700	845098	5160	5222	5284	5346	5408	5470	5532	5594
701	5718	5780	5842	5904	5966	6028	6090	6151	6213
702	6337	6399	6461	6523	6585	6646	6708	6770	6832
703	6955	7017	7079	7141	7202	7264	7326	7388	7449
704	7573	7634	7696	7758	7819	7881	7943	8004	8066
705	848189	8251	8312	8374	8435	8497	8559	8620	8682
706	8805	8866	8928	8989	9051	9112	9174	9235	9297
707	9419	9481	9542	9604	9665	9726	9788	9849	9911
708	850033	0095	0156	0217	0279	0340	0401	0462	0524
709	0646	0707	0769	0830	0891	0952	1014	1075	1136
710	851258	1320	1381	1442	1503	1564	1625	1686	1747
711	1870	1931	1992	2053	2114	2175	2236	2297	2358
712	2480	2541	2602	2663	2724	2785	2846	2907	2968
713	3090	3150	3211	3272	3333	3394	3455	3516	3577
714	3698	3759	3820	3881	3941	4002	4063	4124	4185
715	854306	4367	4428	4488	4549	4610	4670	4731	4792
716	4913	4974	5034	5095	5156	5216	5277	5337	5398
717	5519	5580	5640	5701	5761	5822	5882	5943	6003
718	6124	6185	6245	6306	6366	6427	6487	6548	6608
719	6729	6789	6850	6910	6970	7031	7091	7152	7212
720	857332	7393	7453	7513	7574	7634	7694	7755	7815
721	7935	7995	8056	8116	8176	8236	8297	8357	8417
722	8537	8597	8657	8718	8778	8838	8898	8958	9018
723	9138	9198	9258	9318	9379	9439	9499	9559	9619
724	9739	9799	9859	9918	9978	*0038	*0098	*0158	*0218
725	860338	0398	0458	0518	0578	0637	0697	0757	0817
726	0937	0996	1056	1116	1176	1236	1295	1355	1415
727	1534	1594	1654	1714	1773	1833	1893	1952	2012
728	2131	2191	2251	2310	2370	2430	2489	2549	2608
729	2728	2787	2847	2906	2966	3025	3085	3144	3204
730	863323	3382	3442	3501	3561	3620	3680	3739	3799
731	3917	3977	4036	4096	4155	4214	4274	4333	4392
732	4511	4570	4630	4689	4748	4808	4867	4926	4985
733	5104	5163	5222	5282	5341	5400	5459	5519	5578
734	5696	5755	5814	5874	5933	5992	6051	6110	6169
735	866287	6346	6405	6465	6524	6583	6642	6701	6760
736	6878	6937	6996	7055	7114	7173	7232	7291	7350
737	7467	7526	7585	7644	7703	7762	7821	7880	7939
738	8056	8115	8174	8233	8292	8350	8409	8468	8527
739	8644	8703	8762	8821	8879	8938	8997	9056	9114
740	869232	9290	9349	9408	9466	9525	9584	9642	9701
741	9818	9877	9935	9994	*0053	*0111	*0170	*0228	*0287
742	870404	0462	0521	0579	0638	0696	0755	0813	0872
743	0989	1047	1106	1164	1223	1281	1339	1398	1456
744	1573	1631	1690	1748	1806	1865	1923	1981	2040
745	872156	2215	2273	2331	2389	2448	2506	2564	2622
746	2739	2797	2855	2913	2972	3030	3088	3146	3204
747	3321	3379	3437	3495	3553	3611	3669	3727	3785
748	3902	3960	4018	4076	4134	4192	4250	4308	4366
749	4482	4540	4598	4656	4714	4772	4830	4888	4945
N.	Diff	1	2	3	4	5	6	7	8

PRO. P'TS	Diff.	1	2	3	4	5	6	7	8
	62	6	12	19	25	31	37	43	50
	61	6	12	18	24	31	37	43	49
	60	6	12	18	24	30	36	42	48
	59	6	12	18	24	30	35	41	47
	58	6	12	17	23	29	35	41	46

N.	0	1	2	3	4	5	6	7	8	9	Diff
750	875061	5119	5177	5235	5293	5351	5409	5466	5524	5582	58
751	5640	5698	5756	5813	5871	5929	5987	6045	6102	6160	58
752	6218	6276	6333	6391	6449	6507	6564	6622	6680	6737	58
753	6795	6853	6910	6968	7026	7083	7141	7199	7256	7314	58
754	7371	7429	7487	754	7602	7659	7717	7774	7832	7889	58
755	877947	8004	8062	8119	8177	8234	8292	8349	8407	8464	57
756	8522	8579	8637	8694	8752	8809	8866	8924	8981	9039	57
757	9096	9153	9211	9268	9325	9383	9440	9497	9555	9612	57
758	9669	9726	9784	984	9898	9956	*0013	*0070	*0127	*0185	57
759	880242	0299	0356	0413	0471	0528	0585	0642	0699	0756	57
760	880814	0871	0928	0985	1042	1099	1156	1213	1271	1328	57
761	1385	1442	1499	1556	1613	1670	1727	1784	1841	1898	57
762	1955	2012	2069	2126	2183	2240	2297	2354	2411	2468	57
763	2525	2581	2638	2695	2752	2809	2866	2923	2980	3037	57
764	3093	3150	3207	3264	3321	3377	3434	3491	3548	3605	57
765	883661	3718	3775	3832	3888	3945	4002	4059	4115	4172	57
766	4229	4285	4342	4399	4455	4512	4569	4625	4682	4739	57
767	4795	4852	4909	4965	5022	5078	5135	5192	5248	5305	57
768	5361	5418	5474	5531	5587	5644	5700	5757	5813	5870	57
769	5926	5983	6039	6096	6152	6209	6265	6321	6378	6434	56
770	886491	6547	6604	6660	6716	6773	6829	6885	6942	6998	56
771	7054	71	7167	7223	280	7336	7392	7449	7505	7561	56
772	7617	7674	7730	7786	7842	7898	7955	8011	8067	8123	56
773	8179	8236	8292	8348	8404	8460	8516	8573	8629	8685	56
774	8741	8797	8853	8909	8965	9021	9077	9134	9190	9246	56
775	889302	9358	9414	9470	9526	9582	9638	9694	9750	9806	56
776	9862	9918	9974	*0030	*0086	*0141	*0197	*0253	*0309	*0365	56
777	890421	0477	0533	0589	0645	0700	0756	0812	0868	0924	56
778	0980	1035	1091	1147	1203	1259	1314	1370	1426	1482	56
779	1537	1593	1649	1705	1760	1816	1872	1928	1983	2039	56
780	892095	2150	2206	2262	2317	2373	2429	2484	2540	2595	56
781	2651	2707	2762	2818	2873	2929	2985	3040	3096	3151	56
782	3207	3262	3318	3373	3429	3484	3540	3595	3651	3706	56
783	3762	3817	3873	3928	3984	4039	4094	4150	4205	4261	55
784	4316	4371	4427	4482	4538	4593	4648	4704	4759	4814	55
785	894870	4925	4980	5036	5091	5146	5201	5257	5312	5367	55
786	5423	5478	5533	5588	5644	5699	5754	5809	5864	5920	55
787	5975	6030	6085	6140	6195	6251	6306	6361	6416	6471	55
788	6526	6581	6636	6692	6747	6802	6857	6912	6967	7022	55
789	7077	132	7187	7242	7297	7352	7407	7462	7517	7572	55
790	897627	7682	7737	7792	7847	7902	7957	8012	8067	8122	55
791	8176	8231	8286	8341	8396	8451	8506	8561	8615	8670	55
792	8725	8780	8835	8890	8944	8999	9054	9109	9164	9218	55
793	9273	9328	9383	9437	9492	9547	9602	9656	9711	9766	55
794	9821	9875	9930	9985	*0039	*0094	*0149	*0203	*0258	*0312	55
795	900367	0422	0476	0531	0586	0640	0695	0749	0804	0859	55
796	0913	0968	1022	1077	1131	1186	1240	1295	1349	1404	55
797	1458	1513	1567	1622	1676	1731	1785	1840	1894	1948	54
798	2003	2057	2112	2166	2221	2275	2329	2384	2438	2492	54
799	2547	2601	2655	2710	2764	2818	2873	2927	2981	3036	54
N.	Diff.	1	2	3	4	5	6	7	8	9	Diff

	Diff.	1	2	3	4	5	6	7	8	9	
PR. PTS.	57	6	11	17	23	29	34	40	46	51	57
	56	6	11	17	22	28	34	39	45	50	56
	55	6	11	17	22	28	33	39	44	50	55
	54	5	11	16	22	27	32	38	43	49	54
	Diff.	1	2	3	4	5	6	7	8	9	

N.	0	1	2	3	4	5	6	7	8
800	903090	3144	3199	3253	3307	3361	3416	3470	3524
801	3633	3687	3741	3795	3849	3904	3958	4012	4066
802	4174	4229	4283	4337	4391	4445	4499	4553	4607
803	4716	4770	4824	4878	4932	4986	5040	5094	5148
804	5256	5310	5364	5418	5472	5526	5580	5634	5688
805	905796	5850	5904	5958	6012	6066	6119	6173	6227
806	6335	6389	6443	6497	6551	6604	6658	6712	6766
807	6874	6927	6981	7035	7089	7143	7196	7250	7304
808	7411	7465	7519	7573	7626	7680	7734	7787	7841
809	7949	8002	8056	8110	8163	8217	8270	8324	8378
810	908485	8539	8592	8646	8699	8753	8807	8860	8914
811	9021	9074	9128	9181	9235	9289	9342	9396	9449
812	9556	9610	9663	9716	9770	9823	9877	9930	9984
813	910091	0144	0197	0251	0304	0358	0411	0464	0518
814	0624	0678	0731	0784	0838	0891	0944	0998	1051
815	911158	1211	1264	1317	1371	1424	1477	1530	1584
816	1690	1743	1797	1850	1903	1956	2009	2063	2116
817	2222	2275	2328	2381	2435	2488	2541	2594	2647
818	2753	2806	2859	2913	2966	3019	3072	3125	3178
819	3284	3337	3390	3443	3496	3549	3602	3655	3708
820	913814	3867	3920	3973	4026	4079	4132	4184	4237
821	4343	4396	4449	4502	4555	4608	4660	4713	4766
822	4872	4925	4977	5030	5083	5136	5189	5241	5294
823	5400	5453	5505	5558	5611	5664	5716	5769	5822
824	5927	5980	6033	6085	6138	6191	6243	6296	6349
825	916454	6507	6559	6612	6664	6717	6770	6822	6875
826	6980	7033	7085	7138	7190	7243	7295	7348	7400
827	7506	7558	7611	7663	7716	7768	7820	7873	7925
828	8030	8083	8135	8188	8240	8293	8345	8397	8450
829	8555	8607	8659	8712	8764	8816	8869	8921	8973
830	919078	9130	9183	9235	9287	9340	9392	9444	9496
831	9601	9653	9706	9758	9810	9862	9914	9967	*0019
832	920123	0176	0228	0280	0332	0384	0436	0489	0541
833	0645	0697	0749	0801	0853	0906	0958	1010	1062
834	1166	1218	1270	1322	1374	1426	1478	1530	1582
835	921686	1738	1790	1842	1894	1946	1998	2050	2102
836	2206	2258	2310	2362	2414	2466	2518	2570	2622
837	2725	2777	2829	2881	2933	2985	3037	3089	3140
838	3244	3296	3348	3399	3451	3503	3555	3607	3658
839	3762	3814	3865	3917	3969	4021	4072	4124	4176
840	924279	4331	4383	4434	4486	4538	4589	4641	4693
841	4796	4848	4899	4951	5003	5054	5106	5157	5209
842	5312	5364	5415	5467	5518	5570	5621	5673	5725
843	5828	5879	5931	5982	6034	6085	6137	6188	6240
844	6342	6394	6445	6497	6548	6600	6651	6702	6754
845	926857	6908	6959	7011	7062	7114	7165	7216	7268
846	7370	7422	7473	7524	7576	7627	7678	7730	7781
847	7883	7935	7986	8037	8088	8140	8191	8242	8293
848	8396	8447	8498	8549	8601	8652	8703	8754	8805
849	8908	8959	9010	9061	9112	9163	9215	9266	9317
N.	Diff	1	2	3	4	5	6	7	8

	Diff	1	2	3	4	5	6	7	8
PR. PTS.	55	6	11	17	22	28	33	39	44
	54	5	11	16	22	27	32	38	43
	53	5	11	16	21	27	32	37	42
	52	5	10	16	21	26	31	36	42
	Diff	1	2	3	4	5	6	7	8

N.	0	1	2	3	4	5	6	7	8	9	Diff
850	929419	9470	9521	9572	9623	9674	9725	9776	9827	9879	51
851	9930	9981	*0032	*0083	*0134	*0185	*0236	*0287	*0338	*0389	51
852	930440	0491	0542	0592	0643	0694	0745	0796	0847	0898	51
853	0949	1000	1051	1102	1153	1204	1254	1305	1356	1407	51
854	1458	1509	1560	1610	1661	1712	1763	1814	1865	1915	51
855	931966	2017	2068	2118	2169	2220	2271	2322	2372	2423	51
856	2474	2524	2575	2626	2677	2727	2778	2829	2879	2930	51
857	2981	3031	3082	3133	3183	3234	3285	3335	3386	3437	51
858	3487	3538	3589	3639	3690	3740	3791	3841	3892	3943	51
859	3993	4044	4094	4145	4195	4246	4296	4347	4397	4448	51
860	934498	4549	4599	4650	4700	4751	4801	4852	4902	4953	50
861	5003	5054	5104	5154	5205	5255	5306	5356	5406	5457	50
862	5507	5558	5608	5658	5709	5759	5809	5860	5910	5960	50
863	6011	6061	6111	6162	6212	6262	6313	6363	6413	6463	50
864	6514	6564	6614	6665	6715	6765	6815	6865	6916	6966	50
865	937016	7066	7117	7167	7217	7267	7317	7367	7418	7468	50
866	7518	7568	7618	7668	7718	7769	7819	7869	79 9	7969	50
867	8019	8069	8119	8169	8219	8269	8320	8370	8420	8470	50
868	8520	8570	8620	8670	8720	8770	8820	8870	8920	8970	50
869	9020	9070	9120	9170	9220	9270	9320	9369	9419	9469	50
870	939519	9569	9619	9669	9719	9769	9819	9869	9918	9968	50
871	940018	0068	0118	0168	0218	0267	0317	0367	0417	0467	50
872	0516	0566	0616	0666	0716	0765	0815	0865	0915	0964	50
873	1014	1064	1114	1163	1213	1263	1313	1362	1412	1462	50
874	1511	1561	1611	1660	1710	1760	1809	1859	1909	1958	50
875	942008	2058	2107	2157	2207	2256	2306	2355	2405	2455	50
876	2504	2554	2603	2653	2702	2752	2801	2851	2901	2950	50
877	3000	3049	3099	3148	3198	3247	3297	3346	3396	3445	49
878	3495	3544	3593	3643	3692	3742	3791	3841	3890	3939	49
879	3989	4038	4088	4137	4186	4236	4285	4335	4384	4433	49
880	944483	4532	4581	4631	4680	4729	4779	4828	4877	4927	49
881	4976	5025	5074	5124	5173	5222	5272	5321	5370	5419	49
882	5469	5518	5567	5616	5665	5715	5764	5813	5862	5912	49
883	5961	6010	6059	6108	6157	6207	6256	6305	6354	6403	49
884	6452	6501	6551	6600	6649	6698	6747	6796	6845	6894	49
885	946943	6992	7041	7090	7140	7189	7238	7287	7336	7385	49
886	7434	7483	7532	7581	7630	7679	7728	7777	7826	7875	49
887	7924	7973	8022	8070	8119	8168	8217	8266	8315	8364	49
888	8413	8462	8511	8560	8609	8657	8706	8755	8804	8853	49
889	8902	8951	8999	9048	9097	9146	9195	9244	9292	9341	49
890	949390	9439	9488	9536	9585	9634	9683	9731	9780	9829	49
891	9878	9926	9975	*0024	*0073	*0121	*0170	*0219	*0267	*0316	49
892	950365	0414	0462	0511	0560	0608	0657	0706	0754	0803	49
893	0851	0900	0949	0997	1046	1095	1143	1192	1240	1289	49
894	1338	1386	1435	1483	1532	1580	1629	1677	1726	1775	49
895	951823	1872	1920	1969	2017	2066	2114	2163	2211	2260	48
896	2308	2356	2405	2453	2502	2550	2599	2647	2696	2744	48
897	2792	2841	2889	2938	2986	3034	3083	3131	3180	3228	48
898	3276	3325	3373	3421	3470	3518	3566	3615	3663	3711	48
899	3760	3808	3856	3905	3953	4001	4049	4098	4146	4194	48

N	Diff	1	2	3	4	5	6	7	8	9	Diff
PR. PTS	51	5	10	15	20	26	31	36	41	46	51
	50	5	10	15	20	25	30	35	40	45	50
	49	5	10	15	20	25	29	34	39	44	49
	48	5	10	14	19	24	29	34	38	43	48

N.	0	1	2	3	4	5	6	7	8
900	951243	4291	4339	4387	4435	4484	4532	4580	4628
901	4725	4773	4821	4869	4918	4966	5014	5062	5110
902	5207	5255	5303	5351	5399	5447	5495	5543	5592
903	5688	5736	5784	5832	5880	5928	5976	6024	6072
904	6168	6216	6265	6313	6361	6409	6457	6505	6553
905	956649	6697	6745	6793	6840	6888	6936	6984	7032
906	7128	7176	7224	7272	7320	7368	7416	7464	7512
907	7607	7655	7703	7751	7799	7847	7894	7942	7990
908	8086	8134	8181	8229	8277	8325	8373	8421	8468
909	8564	8612	8659	8707	8755	8803	8850	8898	8946
910	959041	9089	9137	9185	9232	9280	9328	9375	9423
911	9518	9566	9614	9661	9709	9757	9804	9852	9900
912	9995	*0042	*0090	*0138	*0185	*0233	*0280	*0328	*0376
913	960471	0518	0566	0613	0661	0709	0756	0804	0851
914	0946	0994	1041	1089	1136	1184	1231	1279	1326
915	961421	1469	1516	1563	1611	1658	1706	1753	1801
916	1895	1943	1990	2038	2085	2132	2180	2227	2275
917	2369	2417	2464	2511	2559	2606	2653	2701	2748
918	2843	2890	2937	2985	3032	3079	3126	3174	3221
919	3316	3363	3410	3457	3504	3552	3599	3646	3693
920	963788	3835	3882	3929	3977	4024	4071	4118	4165
921	4260	4307	4354	4401	4448	4495	4542	4590	4637
922	4731	4778	4825	4872	4919	4966	5013	5061	5108
923	5202	5249	5296	5343	5390	5437	5484	5531	5578
924	5672	5719	5766	5813	5860	5907	5954	6001	6048
925	966142	6189	6236	6283	6329	6376	6423	6470	6517
926	6611	6658	6705	6752	6799	6845	6892	6939	6986
927	7080	7127	7173	7220	7267	7314	7361	7408	7454
928	7548	7595	7642	7688	7735	7782	7829	7875	7922
929	8016	8062	8109	8156	8203	8249	8296	8343	8390
930	968483	8530	8576	8623	8670	8716	8763	8810	8856
931	8950	8996	9043	9090	9136	9183	9229	9276	9323
932	9416	9463	9509	9556	9602	9649	9695	9742	9789
933	9882	9928	9975	*0021	*0068	*0114	*0161	*0207	*0254
934	970347	0393	0440	0486	0533	0579	0626	0672	0719
935	970812	0858	0904	0951	0997	1044	1090	1137	1183
936	1276	1322	1369	1415	1461	1508	1554	1601	1647
937	1740	1786	1832	1879	1925	1971	2018	2064	2110
938	2203	2249	2295	2342	2388	2434	2481	2527	2573
939	2666	2712	2758	2804	2851	2897	2943	2989	3035
940	973128	3174	3220	3266	3313	3359	3405	3451	349
941	3590	3636	3682	3728	3774	3820	3866	3913	395
942	4051	4097	4143	4189	4235	4281	4327	4374	44
943	4512	4558	4604	4650	4696	4742	4788	4834	48
944	4972	5018	5064	5110	5156	5202	5248	5294	534
945	975432	5478	5524	5570	5616	5662	5707	5753	57
946	5891	5937	5983	6029	6075	6121	6167	6212	62
947	6350	6396	6442	6488	6533	6579	6625	6671	67
948	6808	6854	6900	6946	6992	7037	7083	7129	71
949	7266	7312	7358	7403	7449	7495	7541	7586	76
N	Diff.	1	2	3	4	5	6	7	8

PR. PTS.	Diff.	1	2	3	4	5	6	7
	49	5	10	15	20	25	29	34
	48	5	10	14	19	24	29	34
	47	5	9	14	19	24	28	33
	46	5	9	14	18	23	28	32
	Diff.	1	2	3	4	5	6	7

N.	0	1	2	3	4	5	6	7	8	9	Diff.
950	977724	7769	7815	7861	7906	7952	7998	8043	8089	8135	46
951	8181	8226	8272	8317	8363	8409	8454	8500	8546	8591	46
952	8637	8683	8728	8774	8819	8865	8911	8956	9002	9047	46
953	9093	9138	9184	9230	9275	9321	9366	9412	9457	9503	46
954	9548	9594	9639	9685	9730	9776	9821	9867	9912	9958	46
955	980003	0049	0094	0140	0185	0231	0276	0322	0367	0412	45
956	0458	0503	0549	0594	0640	0685	0730	0776	0821	0867	45
957	0912	0957	1003	1048	1093	1139	1184	1229	1275	1320	45
958	1366	1411	1456	1501	1547	1592	1637	1683	1728	1773	45
959	1819	1864	1909	1954	2000	2045	2090	2135	2181	2226	45
960	982271	2316	2362	2407	2452	2497	2543	2588	2633	2678	45
961	2723	2769	2814	2859	2904	2949	2994	3040	3085	3130	45
962	3175	3220	3265	3310	3356	3401	3446	3491	3536	3581	45
963	3626	3671	3716	3762	3807	3852	3897	3942	3987	4032	45
964	4077	4122	4167	4212	4257	4302	4347	4392	4437	4482	45
965	984527	4572	4617	4662	4707	4752	4797	4842	4887	4932	45
966	4977	5022	5067	5112	5157	5202	5247	5292	5337	5382	45
967	5426	5471	5516	5561	5606	5651	5696	5741	5786	5830	45
968	5875	5920	5965	6010	6055	6100	6144	6189	6234	6279	45
969	6324	6369	6413	6458	6503	6548	6593	6637	6682	6727	45
970	986772	6817	6861	6906	6951	6996	7040	7085	7130	7175	45
971	7219	7264	7309	7353	7398	7443	7488	7532	7577	7622	45
972	7666	7711	7756	7800	7845	7890	7934	7979	8024	8068	45
973	8113	8157	8202	8247	8291	8336	8381	8425	8470	8514	45
974	8559	8604	8648	8693	8737	8782	8826	8871	8916	8960	45
975	989005	9049	9094	9138	9183	9227	9272	9316	9361	9405	45
976	9450	9494	9539	9583	9628	9672	9717	9761	9806	9850	44
977	9895	9939	9983	*0028	*0072	*0117	*0161	*0206	*0250	*0294	44
978	990339	0383	0428	0472	0516	0561	0605	0650	0694	0738	44
979	0783	0827	0871	0916	0960	1004	1049	1093	1137	1182	44
980	991226	1270	1315	1359	1403	1448	1492	1536	1580	1625	44
981	1669	1713	1758	1802	1846	1890	1935	1979	2023	2067	44
982	2111	2156	2200	2244	2288	2333	2377	2421	2465	2509	44
983	2554	2598	2642	2686	2730	2774	2819	2863	2907	2951	44
984	2995	3039	3083	3127	3172	3216	3260	3304	3348	3392	44
985	993436	3480	3524	3568	3613	3657	3701	3745	3789	3833	44
986	3877	3921	3965	4009	4053	4097	4141	4185	4229	4273	44
987	4317	4361	4405	4449	4493	4537	4581	4625	4669	4713	44
988	4757	4801	4845	4889	4933	4977	5021	5065	5108	5152	44
989	5196	5240	5284	5328	5372	5416	5460	5504	5547	5591	44
990	995635	5679	5723	5767	5811	5854	5898	5942	5986	6030	44
991	6074	6117	6161	6205	6249	6293	6337	6380	6424	6468	44
992	6512	6555	6599	6643	6687	6731	6774	6818	6862	6906	44
993	6949	6993	7037	7080	7124	7168	7212	7255	7299	7343	44
994	7386	7430	7474	7517	7561	7605	7648	7692	7736	7779	44
995	997823	7867	7910	7954	7998	8041	8085	8129	8172	8216	44
996	8259	8303	8347	8390	8434	8477	8521	8564	8608	8652	44
997	8695	8739	8782	8826	8869	8913	8956	9000	9043	9087	44
998	9131	9174	9218	9261	9305	9348	9392	9435	9479	9522	44
999	9565	9609	9652	9696	9739	9783	9826	9870	9913	9957	43

N	Diff	1	2	3	4	5	6	7	8	9	Diff
PR. PTS.	46	5	9	14	18	23	28	32	37	41	46
	45	5	9	14	18	23	27	32	36	41	45
	44	4	9	13	18	22	26	31	35	40	44
	43	4	9	13	17	22	26	30	34	39	43
	Diff.	1	2	3	4	5	6	7	8	9	Diff.

N.	0	1	2	3	4	5	6	7	8	9
1000	000000	0043	0087	0130	0174	0217	0260	0304	0347	0391
1001	0434	0477	0521	0564	0608	0651	0694	0738	0781	0824
1002	0868	0911	0954	0998	1041	1084	1128	1171	1214	1258
1003	1301	1344	1388	1431	1474	1517	1561	1604	1647	1690
1004	1734	1777	1820	1863	1907	1950	1993	2036	2080	2123
1005	002166	2209	2252	2296	2339	2382	2425	2468	2512	2555
1006	2598	2641	2684	2727	2771	2814	2857	2900	2943	2986
1007	3029	3073	3116	3159	3202	3245	3288	3331	3374	3417
1008	3461	3504	3547	3590	3633	3676	3719	3762	3805	3848
1009	3891	3934	3977	4020	4063	4106	4149	4192	4235	4278
1010	004321	4364	4407	4450	4493	4536	4579	4622	4665	4708
1011	4751	4794	4837	4880	4923	4966	5009	5052	5095	5138
1012	5181	5223	5266	5309	5352	5395	5438	5481	5524	5567
1013	5609	5652	5695	5738	5781	5824	5867	5909	5952	5995
1014	6038	6081	6124	6166	6209	6252	6295	6338	6380	6423
1015	006466	6509	6552	6594	6637	6680	6723	6765	6808	6851
1016	6894	6936	6979	7022	7065	7107	7150	7193	7236	7278
1017	7321	7364	7406	7449	7492	7534	7577	7620	7662	7705
1018	7748	7790	7833	7876	7918	7961	8004	8046	8089	8132
1019	8174	8217	8259	8302	8345	8387	8430	8472	8515	8558
1020	008600	8643	8685	8728	8770	8813	8856	8898	8941	8983
1021	9026	9068	9111	9153	9196	9238	9281	9323	9366	9408
1022	9451	9493	9536	9578	9621	9663	9706	9748	9791	9833
1023	9876	9918	9961	*0003	*0045	*0088	*0130	*0173	*0215	*0258
1024	010300	0342	0385	0427	0470	0512	0554	0597	0639	0681
1025	010724	0766	0809	0851	0893	0936	0978	1020	1063	1105
1026	1147	1190	1232	1274	1317	1359	1401	1444	1486	1528
1027	1570	1613	1655	1697	1740	1782	1824	1866	1909	1951
1028	1993	2035	2078	2120	2162	2204	2247	2289	2331	2373
1029	2415	2458	2500	2542	2584	2626	2669	2711	2753	2795
1030	012837	2879	2922	2964	3006	3048	3090	3132	3174	3217
1031	3259	3301	3343	3385	3427	3469	3511	3553	3596	3638
1032	3680	3722	3764	3806	3848	3890	3932	3974	4016	4058
1033	4100	4142	4184	4226	4268	4310	4353	4395	4437	4479
1034	4521	4563	4605	4647	4689	4730	4772	4814	4856	4898
1035	014940	4982	5024	5066	5108	5150	5192	5234	5276	5318
1036	5360	5402	5444	5485	5527	5569	5611	5653	5695	5737
1037	5779	5821	5863	5904	5946	5988	6030	6072	6114	6156
1038	6197	6239	6281	6323	6365	6407	6448	6490	6532	6574
1039	6616	6657	6699	6741	6783	6824	6866	6908	6950	6992
1040	017033	7075	7117	7159	7200	7242	7284	7326	7367	7409
1041	7451	7492	7534	7576	7618	7659	7701	7743	7784	7826
1042	7868	7909	7951	7993	8034	8076	8118	8159	8201	8243
1043	8284	8326	8368	8409	8451	8492	8534	8576	8617	8659
1044	8700	8742	8784	8825	8867	8908	8950	8992	9033	9075
1045	019116	9158	9199	9241	9282	9324	9366	9407	9449	9490
1046	9532	9573	9615	9656	9698	9739	9781	9822	9864	9905
1047	9947	9988	*0030	*0071	*0113	*0154	*0195	*0237	*0278	*0320
1048	020361	0403	0444	0486	0527	0568	0610	0651	0693	0734
1049	0775	0817	0858	0900	0941	0982	1024	1065	1107	1148
1050	021189	1231	1272	1313	1355	1396	1437	1479	1520	1561

N	Diff	1	2	3	4	5	6	7	8	9
PR. PTS.	44	4	9	13	18	22	26	31	35	40
	43	4	9	13	17	22	26	30	34	39
	42	4	8	13	17	21	25	29	34	38
	41	4	8	12	16	21	25	29	33	37
	Diff.	1	2	3	4	5	6	7	8	9

TABLE 62

. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
	10.000000		—∞		—∞	60
17.17	.000000	.00	6.463726	5017.17	3.536274	59
34.85	.000000	.00	.764756	2934.85	.235244	58
82.32	.000000	.00	.940847	2082.32	.059153	57
15.17	.000000	.00	7.065786	1615.17	2.934214	56
19.68	10.000000	.02	7.162696	1319.70	2.837304	55
15.78	9.999999	.00	.241878	1115.78	.758122	54
66.53	.999999	.00	.308825	966.53	.691175	53
52.53	.999999	.00	.366817	852.55	.633183	52
62.63	.999999	.02	.417970	762.62	.582030	51
89.87	9.999998	.00	7.463727	689.88	2.536273	50
29.80	.999998	.02	.505120	629.82	.494880	49
79.37	.999997	.00	.542909	579.38	.457091	48
36.42	.999997	.02	.577672	536.42	.422328	47
99.38	.999996	.00	.609857	499.38	.390143	46
67.15	9.999996	.02	7.639820	467.15	2.360180	45
38.80	.999995	.00	.667849	438.83	.332151	44
13.73	.999995	.02	.694179	413.73	.305821	43
91.35	.999994	.02	.719003	391.35	.280997	42
71.27	.999993	.00	.742484	371.28	.257516	41
53.15	9.999993	.02	7.764761	353.17	2.235239	40
36.72	.999992	.02	.785951	336.73	.214049	39
21.75	.999991	.02	.806155	321.75	.193845	38
08.05	.999990	.02	.825460	308.07	.174540	37
95.47	.999989	.00	.843944	295.50	.156056	36
83.88	9.999989	.02	7.861674	283.90	2.138326	35
73.17	.999988	.02	.878708	273.18	.121292	34
63.23	.999987	.02	.895099	263.25	.104901	33
54.00	.999986	.02	.910804	254.00	.089106	32
45.38	.999985	.03	.926134	245.40	.073866	31
37.33	9.999983	.02	7.940858	237.37	2.059142	30
29.80	.999982	.02	.955100	229.82	.044900	29
22.72	.999981	.02	.968889	222.73	.031111	28
16.08	.999980	.02	.982253	216.10	.017747	27
09.82	.999979	.03	.995219	209.83	.004781	26
03.90	9.999977	.02	8.007809	203.92	1.992191	25
98.30	.999976	.02	.020044	198.35	.979956	24
93.03	.999975	.03	.031945	193.03	.968055	23
88.00	.999973	.02	.043527	188.03	.956473	22
83.25	.999972	.02	.054809	183.28	.945191	21
78.73	9.999971	.03	8.065806	178.75	1.934194	20
74.42	.999969	.02	.076531	174.43	.923469	19
70.30	.999968	.03	.086997	170.33	.913003	18
66.40	.999966	.03	.097217	166.43	.902783	17
62.65	.999964	.02	.107203	162.67	.892797	16
59.08	9.999963	.03	8.116963	159.12	1.883037	15
55.65	.999961	.03	.126510	155.68	.873490	14
52.38	.999959	.02	.135851	152.42	.864149	13
49.23	.999958	.03	.144996	149.27	.855004	12
46.23	.999956	.03	.153952	146.25	.846048	11
43.32	9.999954	.03	8.162727	143.35	1.837273	10
40.55	.999952	.03	.171328	140.58	.828672	9
37.87	.999950	.03	.179763	137.88	.820237	8
35.28	.999948	.03	.188036	135.33	.811964	7
32.80	.999946	.03	.196156	132.83	.803844	6
30.42	9.999944	.03	8.204126	130.45	1.795874	5
28.10	.999942	.03	.211953	128.13	.788047	4
25.88	.999940	.03	.219641	125.90	.780359	3
23.72	.999938	.03	.227195	123.77	.772805	2
21.63	.999936	.03	.234621	121.67	.765379	1
	9.999934		8.241921		1.758079	0
1"	Sin.	D. 1".	Cot.	D. 1".	Tan.	M

M.	Sin.	D. 1".	Cos.	D. 1"	Tan.	D. 1"	Cot.	
0	8.241855	119.63	9.999934	03	8.241921	119.68	1.758079	60
1	.249033	117.68	.999932	.05	.249102	117.72	.750898	59
2	.256094	115.80	.999929	03	.256165	115.83	.743835	58
3	.263042	113.98	.999927	.03	.263115	114.02	.736885	57
4	.269881	112.22	.999925	05	.269956	112.25	.730044	56
5	8.276614	110.48	9.999922	.03	8.276691	110.53	1.723309	55
6	.283243	108.83	.999920	.03	.283323	108.88	.716677	54
7	.289773	107.23	.999918	.05	.289856	107.27	.710144	53
8	.296207	105.65	.999915	03	.296292	105.70	.703708	52
9	.302546	104.13	.999913	05	.302634	104.17	.697366	51
10	8.308794	102.67	9.999910	05	8.308884	102.70	1.691116	50
11	.314954	101.22	.999907	03	.315046	101.27	.684954	49
12	.321027	99.82	.999905	05	.321122	99.87	.678878	48
13	.327016	98.47	.999902	.05	.327114	98.52	.672886	47
14	.332924	97.15	.999899	.03	.333025	97.18	.666975	46
15	8.338753	95.85	9.999897	05	8.338856	95.90	1.661144	45
16	.344504	94.62	.999894	.05	.344610	94.65	.655390	44
17	.350181	93.37	.999891	.05	.350289	93.43	.649711	43
18	.355783	92.20	.999888	05	.355895	92.25	.644105	42
19	.361315	91.03	.999885	.05	.361430	91.08	.638570	41
20	8.366777	89.90	9.999882	.05	8.366895	89.95	1.633105	40
21	.372171	88.80	.999879	05	.372292	88.83	.627708	39
22	.377499	87.72	.999876	.05	.377622	87.78	.622378	38
23	.382762	86.67	.999873	.05	.382889	86.72	.617111	37
24	.387962	85.65	.999870	.05	.388092	85.70	.611908	36
25	8.393101	84.63	9.999867	.05	8.393234	84.68	1.606766	35
26	.398179	83.67	.999864	.05	.398315	83.72	.601685	34
27	.403199	82.70	.999861	.05	.403338	82.77	.596662	33
28	.408161	81.78	.999858	.07	.408304	81.82	.591696	32
29	.413068	80.85	.999854	05	.413213	80.92	.586787	31
30	8.417919	79.97	9.999851	.05	8.418068	80.02	1.581932	30
31	.422717	79.08	.999848	.07	.422869	79.15	.577131	29
32	.427462	78.23	.999844	.05	.427618	78.28	.572382	28
33	.432156	77.40	.999841	.05	.432315	77.45	.567685	27
34	.436800	76.57	.999838	07	.436962	76.63	.563038	26
35	8.441394	75.77	9.999834	.05	8.441560	75.83	1.558440	25
36	.445941	74.98	.999831	07	.446110	75.05	.553890	24
37	.450440	74.22	.999827	.05	.450613	74.28	.549387	23
38	.454893	73.47	.999824	07	.455070	73.52	.544930	22
39	.459301	72.73	.999820	07	.459481	72.80	.540519	21
40	8.463665	72.00	9.999816	.05	8.463849	72.05	1.536151	20
41	.467985	71.30	.999813	07	.468172	71.37	.531828	19
42	.472263	70.58	.999809	07	.472454	70.65	.527546	18
43	.476498	69.92	.999805	07	.476693	69.98	.523307	17
44	.480693	69.25	.999801	.07	.480892	69.30	.519108	16
45	8.484848	68.58	9.999797	05	8.485050	68.67	1.514950	15
46	.488963	67.95	.999794	07	.489170	68.00	.510830	14
47	.493040	67.30	.999790	.07	.493250	67.38	.506750	13
48	.497078	66.70	.999786	07	.497293	66.75	.502707	12
49	.501080	66.08	.999782	07	.501298	66.15	.498702	11
50	8.505045	65.48	9.999778	.07	8.505267	65.55	1.494733	10
51	.508974	64.88	.999774	.08	.509200	64.97	.490800	9
52	.512867	64.32	.999769	07	.513098	64.38	.486902	8
53	.516726	63.75	.999765	.07	.516961	63.82	.483039	7
54	.520551	63.20	.999761	.07	.520790	63.27	.479210	6
55	8.524343	62.65	9.999757	07	8.524586	62.72	1.475414	5
56	.528102	62.10	.999753	08	.528349	62.18	.471651	4
57	.531828	61.58	.999748	07	.532080	61.65	.467920	3
58	.535523	61.05	.999744	07	.535779	61.13	.464221	2
59	.539186	60.55	.999740	.08	.539447	60.62	.460553	1
60	8.542819		9.999735		8.543084		1.456916	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1"	Tan.	M.

	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
9	60.05	9.999735	.07	8.543084	60.12	1.456916	60
2	59.55	.999731	.08	.546691	59.62	.453309	59
5	59.07	.999726	.07	.550268	59.15	.449732	58
9	58.58	.999722	.08	.553817	58.65	.446183	57
4	58.10	.999717	.07	.557336	58.20	.442664	56
0	57.65	9.999713	.08	8.560828	57.72	1.439172	55
9	57.20	.999708	.07	.564291	57.27	.435709	54
1	56.75	.999704	.08	.567727	56.83	.432273	53
6	56.30	.999699	.08	.571137	56.38	.428863	52
4	55.87	.999694	.08	.574520	55.95	.425480	51
5	55.43	9.999689	.07	8.577877	55.52	1.422123	50
2	55.02	.999685	.08	.581208	55.10	.418792	49
3	54.60	.999680	.08	.584514	54.68	.415486	48
9	54.20	.999675	.08	.587795	54.27	.412205	47
1	53.78	.999670	.08	591051	53.87	.408949	46
8	53.40	9.999665	.08	8.594283	53.48	1.405717	45
8	53.00	.999660	.08	.597492	53.08	.402508	44
2	52.62	.999655	.08	.600677	52.70	.399323	43
9	52.23	.999650	.08	.603839	52.32	.396161	42
3	51.85	.999645	.08	.606978	51.93	.393022	41
4	51.48	9.999640	.08	8.610094	51.58	1.389906	40
3	51.13	.999635	.10	.613189	51.22	.386811	39
1	50.77	.999629	.08	.616262	50.85	.383738	38
7	50.42	.999624	.08	.619313	50.50	.380687	37
2	50.05	.999619	.08	.622343	50.15	.377657	36
5	49.72	9.999614	.10	8.625352	49.80	1.374648	35
[illegible]	49.38	.999608	.08	.628340	49.47	.371660	34
1	49.05	.999603	.10	.631308	49.13	.368692	33
4	48.70	.999597	.08	.634256	48.80	.365744	32
5	48.40	.999592	.10	.637184	48.48	.362816	31
[illegible]	48.05	9.999586	.08	8.640093	48.15	1.359907	30
3	47.75	.999581	.10	.642982	47.85	.357018	29
3	47.43	.999575	.08	.645853	47.52	.354147	28
4	47.13	.999570	.10	.648704	47.22	.351296	27
2	46.82	.999564	.10	.651537	46.92	.348463	26
[illegible]	46.52	9.999558	.08	8.654352	46.62	1.345648	25
2	46.22	.999553	.10	.657149	46.32	.342851	24
3	45.92	.999547	.10	.659928	46.02	.340072	23
3	45.63	.999541	.10	.662689	45.73	.337311	22
5	45.35	.999535	.10	.665433	45.45	.334567	21
9	45.07	9.999529	.08	8.668160	45.17	1.331840	20
3	44.78	.999524	.10	.670870	44.88	.329130	19
[illegible]	44.52	.999518	.10	.673563	44.60	.326437	18
1	44.23	.999512	.10	.676239	44.35	.323761	17
3	43.97	.999506	.10	.678900	44.07	.321100	16
3	43.70	9.999500	.12	8.681544	43.80	1.318456	15
5	43.45	.999493	.10	.684172	43.53	.315828	14
[illegible]	43.18	.999487	.10	.686784	43.28	.313216	13
3	42.92	.999481	.10	.689381	43.03	.310619	12
5	42.67	.999475	.10	.691963	42.77	.308037	11
8	42.42	9.999469	.10	8.694529	42.53	1.305471	10
3	42.17	999463	.12	.697081	42.27	.302919	9
3	41.93	.999456	.10	.699617	42.03	.300383	8
[illegible]	41.68	.999450	.12	.702139	41.78	.297861	7
3	41.45	.999443	10	.704646	41.57	.295354	6
7	41.20	9.999437	.10	8.707140	41.30	1.292860	5
[illegible]	40.97	.999431	.12	.709618	41.08	.290382	4
7	40.75	.999424	.10	.712083	40.85	.287917	3
2	40.52	.999418	.12	.714534	40.63	.285466	2
3	40.28	.999411	.12	.716972	40.40	.283028	1
[illegible]		9.999404		8.719396		1.280604	0
	D. 1".	Sin.	D. 1"	Cot.	D. 1".	Tan.	M

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot
0	8.718800	40.07	9.999404	.10	8.719396	40.17	1.28
1	.721204	39.85	.999398	.12	.721806	39.97	.27
2	.723595	39.62	.999391	.12	.724204	39.73	.27
3	.725972	39.42	.999384	.10	.726588	39.52	.27
4	.728337	39.18	.999378	.12	.728959	39.30	.27
5	8.730688	38.98	9.999371	.12	8.731317	39.10	1.26
6	.733027	38.78	.999364	.12	.733663	38.88	.26
7	.735354	38.55	.999357	.12	.735996	38.68	.26
8	.737667	38.37	.999350	.12	.738317	38.48	.26
9	.739969	38.17	.999343	.12	.740626	38.27	.25
10	8.742259	37.95	9.999336	.12	8.742922	38.08	1.25
11	.744536	37.77	.999329	.12	.745207	37.87	.25
12	.746802	37.55	.999322	.12	.747479	37.68	.25
13	.749055	37.37	.999315	.12	.749740	37.48	.25
14	.751297	37.18	.999308	.12	.751989	37.30	.24
15	8.753528	36.98	9.999301	.12	8.754227	37.10	1.24
16	.755747	36.80	.999294	.12	.756453	36.92	.24
17	.757955	36.60	.999287	.13	.758668	36.73	.24
18	.760151	36.43	.999279	.12	.760872	36.55	.23
19	.762337	36.23	.999272	.12	.763065	36.35	.23
20	8.764511	36.07	9.999265	.13	8.765246	36.18	1.23
21	.766675	35.88	.999257	.12	.767417	36.02	.23
22	.768828	35.70	.999250	.13	.769578	35.82	.23
23	.770970	35.52	.999242	.12	.771727	35.65	.22
24	.773101	35.37	.999235	.13	.773866	35.48	.22
25	8.775223	35.17	9.999227	.12	8.775995	35.32	1.22
26	.777333	35.02	.999220	.13	.778114	35.13	.22
27	.779434	34.83	.999212	.12	.780222	34.97	.2
28	.781524	34.68	.999205	.13	.782320	34.80	.2
29	.783605	34.50	.999197	.13	.784408	34.63	.2
30	8.785675	34.35	9.999189	.13	8.786486	34.47	1.2
31	.787736	34.18	.999181	.12	.788554	34.32	.2
32	.789787	34.02	.999174	.13	.790613	34.15	.2
33	.791828	33.85	.999166	.13	.792662	33.98	.2
34	.793859	33.70	.999158	.13	.794701	33.83	.2
35	8.795881	33.55	9.999150	.13	8.796731	33.68	1.2
36	.797894	33.38	.999142	.13	.798752	33.52	.2
37	.799897	33.25	.999134	.13	.800763	33.37	.1
38	.801892	33.07	.999126	.13	.802765	33.22	.1
39	.803876	32.93	.999118	.13	.804758	33.07	.1
40	8.805852	32.78	9.999110	.13	8.806742	32.92	1.1
41	.807819	32.63	.999102	.13	.808717	32.77	.1
42	.809777	32.48	.999094	.13	.810683	32.63	.1
43	.811726	32.35	.999086	.15	.812641	32.47	.1
44	.813667	32.20	.999077	.13	.814589	32.33	.1
45	8.815599	32.05	9.999069	.13	8.816529	32.20	1.1
46	.817522	31.90	.999061	.13	.818461	32.05	.1
47	.819436	31.78	.999053	.15	.820384	31.90	.1
48	.821343	31.62	.999044	.13	.822298	31.78	.1
49	.823240	31.50	.999036	.15	.824205	31.63	.1
50	8.825130	31.35	9.999027	.13	8.826103	31.48	1.1
51	.827011	31.22	.999019	.15	.827992	31.37	.1
52	.828884	31.08	.999010	.13	.829874	31.23	.1
53	.830749	30.97	.999002	.15	.831748	31.08	.1
54	.832607	30.82	.998993	.15	.833613	30.97	.1
55	8.834456	30.68	9.998984	.13	8.835471	30.83	1.1
56	.836297	30.55	.998976	.15	.837321	30.70	.1
57	.838130	30.43	.998967	.15	.839163	30.58	.1
58	.839956	30.30	.998958	.13	.840998	30.45	.1
59	.841774	30.18	.998950	.15	.842825	30.32	.1
60	8.843585		9.998941		8.844644		1.1
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	

Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
8.843585	30.03	9.998941	.15	8.844644	30.18	1.155356	60
.845387	29.93	.998932	.15	.846455	30.08	.153545	59
.847183	29.80	.998923	.15	.848260	29.95	.151740	58
.848971	29.67	.998914	.15	.850057	29.82	.149943	57
.850751	29.57	.998905	.15	.851846	29.70	.148154	56
8.852525	29.43	9.998896	.15	8.853628	29.58	1.146372	55
.854291	29.30	.998887	.15	.855403	29.47	.144597	54
.856049	29.20	.998878	.15	.857171	29.35	.142829	53
.857801	29.08	.998869	.15	.858932	29.23	.141068	52
.859546	28.95	.998860	.15	.860686	29.12	.139314	51
8.861283	28.85	9.998851	.17	8.862433	29.00	1.137567	50
.863014	28.73	.998841	.15	.864173	28.88	.135827	49
.864738	28.62	.998832	.15	.865906	28.77	.134094	48
.866455	28.50	.998823	.17	.867632	28.65	.132368	47
.868165	28.38	.998813	.15	.869351	28.55	.130649	46
8.869868	28.28	9.998804	.15	8.871064	28.43	1.128936	45
.871565	28.17	.998795	.17	.872770	28.32	.127230	44
.873255	28.05	.998785	.15	.874469	28.22	.125531	43
.874938	27.95	.998776	.17	.876162	28.12	.123838	42
.876615	27.83	.998766	.15	.877849	28.00	.122151	41
8.878285	27.73	9.998757	.17	8.879529	27.88	1.120471	40
.879949	27.63	.998747	.15	.881202	27.78	.118798	39
.881607	27.52	.998738	.17	.882869	27.68	.117131	38
.883258	27.42	.998728	.17	.884530	27.58	.115470	37
.884903	27.32	.998718	.17	.886185	27.47	.113815	36
8.886542	27.20	9.998708	.15	8.887833	27.38	1.112167	35
.888174	27.12	.998699	.17	.889476	27.27	110524	34
.889801	27.00	.998689	.17	.891112	27.17	.108888	33
.891421	26.90	.998679	.17	.892742	27.07	.107258	32
.893035	26.80	.998669	.17	.894366	26.97	.105634	31
8.894643	26.72	9.998659	.17	8.895984	26.87	1.104016	30
.896246	26.60	.998649	.17	.897596	26.78	.102404	29
.897842	26.50	.998639	.17	.899203	26.67	.100797	28
.899432	26.42	.998629	.17	.900803	26.58	.099197	27
.901017	26.32	.998619	.17	.902398	26.48	.097602	26
8.902596	26.22	9.998609	.17	8.903987	26.38	1.096013	25
.904169	26.12	.998599	.17	905570	26.28	.094430	24
.905736	26.00	.998589	.18	.907147	26.20	.092853	23
.907297	25.93	.998578	.17	.908719	26.10	.091281	22
.908853	25.85	.998568	.17	.910285	26.02	.089715	21
8.910404	25.75	9.998558	.17	8.911846	25.92	1.088154	20
.911949	25.65	.998548	.18	.913401	25.83	.086599	19
.913488	25.57	.998537	.17	.914951	25.73	.085049	18
.915022	25.47	.998527	.18	.916495	25.65	.083505	17
.916550	25.38	.998516	.17	.918034	25.57	.081966	16
8.918073	25.30	9.998506	.18	8.919568	25.47	1 080432	15
.919591	25.20	.998495	.17	.921096	25.38	.078904	14
.921103	25.12	.998485	.18	.922619	25.28	.077381	13
.922610	25.03	.998474	.17	.924136	25.22	.075864	12
.924112	24.95	.998464	.18	.925649	25.12	.074351	11
8.925609	24.85	9.998453	.18	8.927156	25.03	1.072844	10
.927100	24.78	.998442	.18	.928653	24.95	.071342	9
.928587	24.68	.998431	.17	.930155	24.87	.069845	8
.930068	24.60	.998421	.18	.931647	24.78	.068353	7
.931544	24.52	.998410	.18	.933134	24.70	.066866	6
8.933015	24.43	9.998399	.18	8.934616	24.62	1.065384	5
.934481	24.35	.998388	.18	.936093	24.53	.063907	4
.935942	24.27	.998377	.18	.937565	24.45	.062435	3
.937398	24.20	.998366	.18	.939032	24.37	.060968	2
.938850	24.10	.998355	.18	.940494	24.30	.059506	1
8.940296		9.998344		8.941952		1.058048	0
Cos.	**D. 1″.**	**Sin.**	**D. 1″.**	**Cot.**	**D. 1″.**	**Tan.**	**M**

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	8.940296	24.03	9.998344	.18	8.941952	24.20	1.058048	60
1	.941738	23.93	.998333	.18	.943404	24.13	.056596	59
2	.943174	23.87	.998322	.18	.944852	24.05	.055148	58
3	.944606	23.80	.998311	.18	.946295	23.98	.053705	57
4	.946034	23.70	.998300	.18	.947734	23.90	.052266	56
5	8.947456	23.63	9.998289	.20	8.949168	23.82	1.050832	55
6	.948874	23.55	.998277	.18	.950597	23.73	.049403	54
7	.950287	23.48	.998266	.18	.952021	23.67	.047979	53
8	.951696	23.40	.998255	.20	.953441	23.58	.046559	52
9	.953100	23.32	.998243	.18	.954856	23.52	.045144	51
10	8.954499	23.25	9.998232	.20	8.956267	23.45	1.043733	50
11	.955894	23.17	.998220	.18	.957674	23.35	.042326	49
12	.957284	23.10	.998209	.20	.959075	23.30	.040925	48
13	.958670	23.03	.998197	.18	.960473	23.22	.039527	47
14	.960052	22.95	.998186	.20	.961866	23.15	.038134	46
15	8.961429	22.87	9.998174	.18	8.963255	23.07	1.036745	45
16	.962801	22.82	.998163	.20	.964639	23.00	.035361	44
17	.964170	22.73	.998151	.20	.966019	22.92	.033981	43
18	.965534	22.65	.998139	.18	.967394	22.87	.032606	42
19	.966893	22.60	.998128	.20	.968766	22.78	.031234	41
20	8.968249	22.52	9.998116	.20	8.970133	22.72	1.029867	40
21	.969600	22.45	.998104	.20	.971496	22.65	.028504	39
22	.970947	22.37	.998092	.20	.972855	22.57	.027145	38
23	.972289	22.32	.998080	.20	.974209	22.52	.025791	37
24	.973628	22.23	.998068	.20	.975560	22.43	.024440	36
25	8.974962	22.18	9.998056	.20	8.976906	22.37	1.023094	35
26	.976293	22.10	.998044	.20	.978248	22.30	.021752	34
27	.977619	22.03	.998032	.20	.979586	22.25	.020414	33
28	.978941	21.97	.998020	20	.980921	22.17	.019079	32
29	.980259	21.90	.998008	.20	.982251	22.10	.017749	31
30	8.981573	21.83	9.997996	.20	8.983577	22.03	1.016423	30
31	.982883	21.77	.997984	.20	.984899	21.97	.015101	29
32	.984189	21.70	.997972	22	.986217	21.92	.013783	28
33	.985491	21.63	.997959	.20	.987532	21.83	.012468	27
34	.986789	21.57	.997947	.20	.988842	21.78	.011158	26
35	8.988083	21.52	9.997935	.22	8.990149	21.70	1.009851	25
36	.989374	21.43	.997922	.20	.991451	21.65	.008549	24
37	.990660	21.38	.997910	.22	.992750	21.58	.007250	23
38	.991943	21.32	.997897	.20	.994045	21.53	.005955	22
39	.993222	21.25	.997885	.22	.995337	21.45	.004663	21
40	8.994497	21.18	9.997872	.20	8.996624	21.40	1.003376	20
41	.995768	21.13	.997860	.22	.997908	21.33	.002092	19
42	.997036	21.05	.997847	.20	.999188	21.28	.000812	18
43	.998299	21.02	.997835	22	9.000465	21.22	0.999535	17
44	.999560	20.93	.997822	.22	.001738	21.15	.998262	16
45	9.000816	20.88	9.997809	.20	9.003007	21.08	0.996993	15
46	.002069	20.82	.997797	.22	.004272	21.03	.995728	14
47	.003318	20.75	.997784	.22	.005534	20.97	.994466	13
48	.004563	20.70	.997771	.22	.006792	20.92	.993208	12
49	.005805	20.65	.997758	.22	.008047	20.85	.991953	11
50	9.007044	20.57	9.997745	22	9.009298	20.80	0.990702	10
51	.008278	20.53	.997732	.22	.010546	20.73	.989454	9
52	.009510	20.45	.997719	.22	.011790	20.68	.988210	8
53	.010737	20.42	.997706	.22	.013031	20.62	.986969	7
54	.011962	20.33	.997693	.22	.014268	20.57	.985732	6
55	9.013182	20.30	9.997680	.22	9.015502	20.50	0.984498	5
56	.014400	20.22	.997667	.22	.016732	20.45	.983268	4
57	.015613	20.18	.997654	.22	.017959	20.40	.982041	3
58	.016824	20.12	.997641	.22	.019183	20.33	.980817	2
59	.018031	20.07	.997628	.23	.020403	20.28	.979597	1
60	9.019235		9.997614		9.021620		0.978380	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	

	D. 1″.	Cos.	D. 1″	Tan.	D. 1″.	Cot.	
35	20.00	9.997614	.22	9.021620	20.23	0.978380	60
35	19.95	.997601	.22	.022834	20.17	.977166	59
32	19.88	.997588	.23	.024044	20.12	.975956	58
25	19.85	.997574	.22	.025251	20.07	.974749	57
16	19.78	.997561	.23	.026455	20.00	.973545	56
03	19.72	9.997547	.22	9.027655	19.95	0.972345	55
86	19.68	.997534	.23	.028852	19.90	.971148	54
67	19.62	.997520	.22	.030046	19.85	.969954	53
44	19.57	.997507	.23	.031237	19.80	.968763	52
18	19.52	.997493	.22	.032425	19.73	.967575	51
89	19.47	9.997480	.23	9.033609	19.70	0.966391	50
57	19.40	.997466	.23	.034791	19.63	.965209	49
21	19.35	.997452	.22	.035969	19.58	.964031	48
82	19.32	.997439	.23	.037144	19.53	.962856	47
41	19.25	.997425	.23	.038316	19.48	.961684	46
96	19.20	9.997411	.23	9.039485	19.43	0.960515	45
48	19.15	.997397	.23	.040651	19.37	.959349	44
97	19.08	.997383	.23	.041813	19.33	.958187	43
42	19.05	.997369	.23	.042973	19.28	.957027	42
85	19.00	.997355	.23	.044130	19.23	.955870	41
25	18.95	9.997341	.23	9.045284	19.17	0.954716	40
62	18.88	.997327	.23	.046434	19.13	.953566	39
95	18.85	.997313	.23	.047582	19.08	.952418	38
26	18.80	.997299	.23	.048727	19.03	.951273	37
54	18.75	.997285	.23	.049869	18.98	.950131	36
79	18.68	9.997271	.23	9.051008	18.93	0.948992	35
00	18.65	.997257	.25	.052144	18.88	.947856	34
19	18.60	.997242	.23	.053277	18.83	.946723	33
35	18.57	.997228	.23	.054407	18.80	.945593	32
49	18.50	.997214	.25	.055535	18.73	.944465	31
59	18.45	9.997199	.23	9.056659	18.70	0.943341	30
66	18.42	.997185	.25	.057781	18.65	.942219	29
71	18.35	.997170	.23	.058900	18.60	.941100	28
72	18.32	.997156	.25	.060016	18.57	.939984	27
71	18.27	.997141	.23	.061130	18.50	.938870	26
67	18.22	9.997127	.25	9.062240	18.47	0.937760	25
60	18.18	.997112	.23	.063348	18.42	.936652	24
51	18.13	.997098	.25	.064453	18.38	.935547	23
39	18.08	.997083	.25	.065556	18.32	.934444	22
24	18.03	.997068	.25	.066655	18.28	.933345	21
06	17.98	9.997053	.23	9.067752	18.23	0.932248	20
85	17.95	.997039	.25	.068846	18.20	.931154	19
62	17.90	.997024	.25	.069938	18.15	.930062	18
36	17.85	.997009	.25	.071027	18.10	.928973	17
07	17.82	.996994	.25	.072113	18.07	.927887	16
76	17.77	9.996979	.25	9.073197	18.02	0.926803	15
42	17.73	.996964	.25	.074278	17.97	.925722	14
06	17.67	.996949	.25	.075356	17.93	.924644	13
66	17.63	.996934	.25	.076432	17.88	.923568	12
24	17.60	.996919	.25	.077505	17.85	.922495	11
80	17.55	9.996904	.25	9.078576	17.80	0.921424	10
33	17.50	.996889	.25	.079644	17.77	.920356	9
83	17.47	.996874	.27	.080710	17.72	.919290	8
31	17.42	.996858	.25	.081773	17.67	.918227	7
76	17.38	.996843	.25	.082833	17.63	.917167	6
19	17.33	9.996828	.27	9.083891	17.60	0.916109	5
59	17.30	.996812	.25	.084947	17.55	.915053	4
97	17.25	.996797	.25	.086000	17.50	.914000	3
32	17.20	.996782	.27	.087050	17.47	.912950	2
64	17.17	.996766	.25	.088098	17.43	.911902	1
4		9.996751		9.089144		0.910856	0
	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.085894	17.13	9.996751	.27	9.089144	17.38	0.910856	60
1	.086922	17.08	.996735	.25	.090187	17.35	.909813	59
2	.087947	17.05	.996720	.27	.091228	17.30	.908772	58
3	.088970	17.00	.996704	.27	.092266	17.27	.907734	57
4	.089990	16.97	.996688	.25	.093302	17.23	.906698	56
5	9.091008	16.93	9.996673	.27	9.094336	17.18	0.905664	55
6	.092024	16.88	.996657	.27	.095367	17.13	.904633	54
7	.093037	16.83	.996641	.27	.096395	17.12	.903605	53
8	.094047	16.82	.996625	.25	.097422	17.07	.902578	52
9	.095056	16.77	.996610	.27	.098446	17.03	.901554	51
10	9.096062	16.72	9.996594	.27	9.099468	16.98	0.900532	50
11	.097065	16.68	.996578	.27	.100487	16.95	.899513	49
12	.098066	16.65	.996562	.27	.101504	16.92	.898496	48
13	.099065	16.62	.996546	.27	.102519	16.88	.897481	47
14	.100062	16.57	.996530	.27	.103532	16.83	.896468	46
15	9.101056	16.53	9.996514	.27	9.104542	16.80	0.895458	45
16	.102048	16.48	.996498	.27	.105550	16.77	.894450	44
17	.103037	16.47	.996482	.28	.106556	16.72	.893444	43
18	.104025	16.42	.996465	.27	.107559	16.68	.892441	42
19	.105010	16.37	.996449	.27	.108560	16.65	.891440	41
20	9.105992	16.35	9.996433	.27	9.109559	16.62	0.890441	40
21	.106973	16.30	.996417	.28	.110556	16.58	.889444	39
22	.107951	16.27	.996400	.27	.111551	16.53	.888449	38
23	.108927	16.23	.996384	.27	.112543	16.50	.887457	37
24	.109901	16.20	.996368	.28	.113533	16.47	.886467	36
25	9.110873	16.15	9.996351	.27	9.114521	16.43	0.885479	35
26	.111842	16.12	.996335	.28	.115507	16.40	.884493	34
27	.112809	16.08	.996318	.27	.116491	16.35	.883509	33
28	.113774	16.05	.996302	.28	.117472	16.33	.882528	32
29	.114737	16.02	.996285	.27	.118452	16.28	.881548	31
30	9.115698	15.97	9.996269	.28	9.119429	16.25	0.880571	30
31	.116656	15.95	.996252	.28	.120404	16.22	.879596	29
32	.117613	15.90	.996235	.27	.121377	16.18	.878623	28
33	.118567	15.87	.996219	.28	.122348	16.15	.877652	27
34	.119519	15.83	.996202	.28	.123317	16.12	.876683	26
35	9.120469	15.80	9.996185	.28	9.124284	16.08	0.875716	25
36	.121417	15.75	.996168	.28	.125249	16.03	.874751	24
37	.122362	15.73	.996151	.28	.126211	16.02	.873789	23
38	.123306	15.70	.996134	.28	.127172	15.97	.872828	22
39	.124248	15.65	.996117	.28	.128130	15.95	.871870	21
40	9.125187	15.63	9.996100	.28	9.129087	15.90	0.870913	20
41	.126125	15.58	.996083	.28	.130041	15.88	.869959	19
42	.127060	15.55	.996066	.28	.130994	15.83	.869006	18
43	.127993	15.53	.996049	.28	.131944	15.82	.868056	17
44	.128925	15.48	.996032	.28	.132893	15.77	.867107	16
45	9.129854	15.45	9.996015	.28	9.133839	15.75	0.866161	15
46	.130781	15.42	.995998	.30	.134784	15.70	.865216	14
47	.131706	15.40	.995980	.28	.135726	15.68	.864274	13
48	.132630	15.35	.995963	.28	.136667	15.63	.863333	12
49	.133551	15.32	.995946	.30	.137605	15.62	.862395	11
50	9.134470	15.28	9.995928	.28	9.138542	15.57	0.861458	10
51	.135387	15.27	.995911	.28	.139476	15.55	.860524	9
52	.136303	15.22	.995894	.30	.140409	15.52	.859591	8
53	.137216	15.20	.995876	.28	.141340	15.48	.858660	7
54	.138128	15.15	.995859	.30	.142269	15.45	.857731	6
55	9.139037	15.12	9.995841	.30	9.143196	15.42	0.856804	5
56	.139944	15.10	.995823	.28	.144121	15.38	.855879	4
57	.140850	15.07	.995806	.30	.145044	15.37	.854956	3
58	.141754	15.02	.995788	.28	.145966	15.32	.854034	2
59	.142655	15.00	.995771	.30	.146885	15.30	.853115	1
60	9.143555		9.995753		9.147803		0.852197	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	

D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
14.97	9.995753	.30	9.147803	15.25	0.852197	60
14.93	.995735	.30	.148718	15.23	.851282	59
14.90	.995717	.30	.149632	15.20	.850368	58
14.88	.995699	.30	.150544	15.17	.849456	57
14.83	.995681	.28	.151454	15.15	848546	56
14.82	9.995664	.30	9.152363	15.10	0.847637	55
14.78	.995646	30	.153269	15.08	.846731	54
14.73	995628	.30	.154174	15.05	.845826	53
14.72	.995610	.32	.155077	15.02	.844923	52
14.70	.995591	.30	.155978	14.98	.844022	51
14.65	9.995573	.30	9.156877	14.97	0.843123	50
14.63	995555	.30	.157775	14.93	.842225	49
14.58	.995537	.30	.158671	14.90	.841329	48
14.57	.995519	.30	.159565	14.87	.840435	47
14.55	.995501	.32	.160457	14.83	.839543	46
14.50	9.995482	30	9.161347	14.82	0.838653	45
14.48	.995464	.30	.162236	14.78	.837764	44
14.43	.995446	32	.163123	14.75	836877	43
14.43	.995427	.30	.164008	14.73	.835992	42
14.38	.995409	.32	.164892	14.70	.835108	41
14.35	9.995390	.30	9.165774	14.67	0.834226	40
14.33	.995372	32	.166654	14.63	.833346	39
14.30	.995353	.32	.167532	14.62	.832468	38
14.28	.995334	30	.168409	14.58	.831591	37
14.23	.995316	.32	.169284	14.55	.830716	36
14.22	9.995297	32	9.170157	14.53	0.829843	35
14.20	.995278	30	.171029	14.50	.828971	34
14.15	.995260	.32	.171899	14.47	.828101	33
14.13	.995241	.32	.172767	14.45	827233	32
14.10	.995222	.32	.173634	14.42	.826366	31
14.08	9.995203	.32	9.174499	14.38	0.825501	30
14.03	.995184	.32	.175362	14.37	.824638	29
14.02	.995165	.32	.176224	14.33	.823776	28
14.00	.995146	.32	.177084	14.30	.822916	27
13.97	.995127	32	177942	14.28	.822058	26
13.93	9.995108	.32	9.178799	14.27	0.821201	25
13.90	.995089	32	.179655	14.22	.820345	24
13.88	.995070	.32	.180508	14.20	.819492	23
13.85	.995051	.32	181360	14.18	.818640	22
13.83	.995032	.32	.182211	14.13	.817789	21
13.80	9.995013	.33	9.183050	14.13	0.816941	20
13.77	.994993	.32	.183907	14.08	.816093	19
13.75	.994974	.32	.184752	14.08	.815248	18
13.72	.994955	.33	.185597	14.03	.814403	17
13.70	.994935	32	.186430	14.02	.813561	16
13.67	9.994916	.33	9.187280	14.00	0.812720	15
13.63	.994896	.32	.188120	13.97	.811880	14
13.62	.994877	.33	.188958	13.93	.811042	13
13.58	.994857	.32	.189794	13.92	.810206	12
13.57	.994838	.33	.190629	13.88	.809371	11
13.53	9.994818	.33	9.191462	13.87	0.808538	10
13.52	.994798	.32	.192294	13.83	807706	9
13.48	.994779	.33	.193124	13.82	.806876	8
13.45	.994759	33	.193953	13.78	.806047	7
13.43	994739	32	.194780	13.77	.805220	6
13.42	9.994720	33	9.195606	13.73	0.804394	5
13.38	.994700	.33	.196430	13.72	.803570	4
13.35	.994680	33	.197253	13.68	.802747	3
13.33	.994660	.33	.198074	13.67	.801926	2
13.30	994640	.33	.198894	13.65	.801106	1
	9.994620		9.199713		0.800287	0
D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M

9°

LOGARITHMIC SINES

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot
0	9.194332	13.28	9.994620	.33	9.199713	13.60	0.80
1	.195129	13.27	.994600	.33	.200529	13.60	.79
2	.195925	13.23	.994580	.33	.201345	13.57	.79
3	.196719	13.20	.994560	.33	.202159	13.53	.79
4	.197511	13.18	.994540	.35	.202971	13.52	.79
5	9.198302	13.15	9.994519	.33	9.203782	13.50	0.79
6	.199091	13.13	.994499	.33	.204592	13.47	.79
7	.199879	13.12	.994479	.33	.205400	13.45	.79
8	.200666	13.08	.994459	.35	.206207	13.43	.79
9	.201451	13.05	.994438	.33	.207013	13.40	.79
10	9.202234	13.05	9.994418	.33	9.207817	13.37	0.79
11	.203017	13.00	.994398	.35	.208619	13.35	.79
12	.203797	13.00	.994377	.33	.209420	13.33	.79
13	.204577	12.95	.994357	.35	.210220	13.30	.78
14	.205354	12.95	.994336	.33	.211018	13.28	.78
15	9.206131	12.92	9.994316	.35	9.211815	13.27	0.78
16	.206906	12.88	.994295	.35	.212611	13.23	.78
17	.207679	12.88	.994274	.33	.213405	13.22	.78
18	.208452	12.83	.994254	.35	.214198	13.18	.78
19	.209222	12.83	.994233	.35	.214989	13.18	.78
20	9.209992	12.80	9.994212	.35	9.215780	13.13	0.78
21	.210760	12.77	.994191	.33	.216568	13.13	.78
22	.211526	12.75	.994171	.35	.217356	13.10	.78
23	.212291	12.73	.994150	.35	.218142	13.07	.78
24	.213055	12.72	.994129	.35	.218926	13.07	.78
25	9.213818	12.68	9.994108	.35	9.219710	13.03	0.78
26	.214579	12.65	.994087	.35	.220492	13.00	.77
27	.215338	12.65	.994066	.35	.221272	13.00	.77
28	.216097	12.62	.994045	.35	.222052	12.97	.77
29	.216854	12.58	.994024	.35	.222830	12.95	.77
30	9.217609	12.57	9.994003	.35	9.223607	12.92	0.77
31	.218363	12.55	.993982	.37	.224382	12.90	.77
32	.219116	12.53	.993960	.35	.225156	12.88	.77
33	.219868	12.50	.993939	.35	.225929	12.85	.77
34	.220618	12.48	.993918	35	.226700	12.85	.77
35	9.221367	12.47	9.993897	.37	9.227471	12.80	0.77
36	.222115	12.43	.993875	.35	.228239	12.80	.77
37	.222861	12.42	.993854	.37	.229007	12.77	.77
38	.223606	12.38	.993832	.35	.229773	12.77	.77
39	.224349	12.38	.993811	.37	.230539	12.72	.76
40	9.225092	12.35	9.993789	.35	9.231302	12.72	0.76
41	.225833	12.33	.993768	.37	.232065	12.68	.76
42	.226573	12.30	.993746	.35	.232826	12.67	.76
43	.227311	12.28	.993725	.37	.233586	12.65	.76
44	.228048	12.27	.993703	.37	.234345	12.63	.76
45	9.228784	12.23	9.993681	.35	9.235103	12.60	0.76
46	.229518	12.23	.993660	.37	.235859	12.58	.76
47	.230252	12.20	.993638	.37	.236614	12.57	.76
48	.230984	12.18	.993616	.37	.237368	12.53	.76
49	.231715	12.15	.993594	.37	.238120	12.53	.76
50	9.232444	12.13	9.993572	.37	9.238872	12.50	0.76
51	.233172	12.12	.993550	.37	.239622	12.48	.76
52	.233899	12.10	.993528	.37	.240371	12.45	.75
53	.234625	12.07	.993506	.37	.241118	12.45	.75
54	.235349	12.07	.993484	.37	.241865	12.42	.75
55	9.236073	12.03	9.993462	.37	9.242610	12.40	0.75
56	.236795	12.00	.993440	.37	.243354	12.38	.75
57	.237515	12.00	.993418	.37	244097	12.37	.75
58	.238235	11.97	.993396	.37	.244839	12.33	.75
59	.238953	11.95	.993374	.38	.245579	12.33	.754
60	9.239670		9.993351		9.246319		0.75
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Ta

9°

	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
670	11.93	9.993351	.37	9.246319	12.30	0.753681	60
386	11.92	.993329	.37	.247057	12.28	.752943	59
101	11.88	.993307	.38	.247794	12.27	.752206	58
814	11.87	.993284	.37	.248530	12.23	.751470	57
526	11.85	.993262	.37	.249264	12.23	.750736	56
237	11.83	9.993240	.38	9.249998	12.20	0.750002	55
947	11.82	.993217	.37	.250730	12.18	.749270	54
656	11.78	.993195	.38	.251461	12.17	.748539	53
363	11.77	.993172	.38	.252191	12.15	.747809	52
069	11.77	.993149	.37	.252920	12.13	.747080	51
775	11.72	9.993127	.38	9.253648	12.10	0.746352	50
478	11.72	.993104	.38	.254374	12.10	.745626	49
181	11.70	.993081	.37	.255100	12.07	.744900	48
883	11.67	.993059	.38	.255824	12.05	.744176	47
583	11.65	.993036	.38	.256547	12.03	.743453	46
282	11.63	9.993013	.38	9.257269	12.02	0.742731	45
980	11.62	.992990	.38	.257990	12.00	.742010	44
677	11.60	.992967	.38	.258710	11.98	.741290	43
373	11.57	.992944	.38	.259429	11.95	.740571	42
067	11.57	.992921	.38	.260146	11.95	.739854	41
761	11.53	9.992898	.38	9.260863	11.92	0.739137	40
453	11.52	.992875	.38	.261578	11.90	.738422	39
144	11.50	.992852	.38	.262292	11.88	.737708	38
834	11.48	.992829	.38	.263005	11.87	.736995	37
523	11.47	.992806	.38	.263717	11.85	.736283	36
211	11.45	9.992783	.40	9.264428	11.83	0.735572	35
898	11.42	.992759	.38	.265138	11.82	.734862	34
583	11.42	.992736	.38	.265847	11.80	.734153	33
268	11.38	.992713	.38	.266555	11.77	.733445	32
951	11.37	.992690	.40	.267261	11.77	.732739	31
633	11.35	9.992666	.38	9.267967	11.73	0.732033	30
314	11.33	.992643	.40	.268671	11.73	.731329	29
994	11.32	.992619	.38	.269375	11.70	.730625	28
673	11.30	.992596	.40	.270077	11.70	.729923	27
351	11.27	.992572	.38	.270779	11.67	.729221	26
027	11.27	9.992549	.40	9.271479	11.65	0.728521	25
703	11.23	.992525	.40	.272178	11.63	.727822	24
377	11.23	.992501	.38	.272876	11.62	.727124	23
051	11.20	.992478	.40	.273573	11.60	.726427	22
723	11.20	.992454	.40	.274269	11.58	.725731	21
395	11.17	9.992430	.40	9.274964	11.57	0.725036	20
065	11.15	.992406	.40	.275658	11.55	.724342	19
734	11.13	.992382	.38	.276351	11.53	.723649	18
402	11.12	.992359	.40	.277043	11.52	.722957	17
069	11.10	.992335	.40	.277734	11.50	.722266	16
735	11.08	9.992311	.40	9.278424	11.48	0.721576	15
400	11.07	.992287	.40	.279113	11.47	.720887	14
064	11.03	.992263	.40	.279801	11.45	.720199	13
726	11.03	.992239	.42	.280488	11.43	.719512	12
388	11.02	.992214	.40	.281174	11.40	.718826	11
049	10.98	9.992190	.40	9.281858	11.40	0.718142	10
708	10.98	.992166	.40	.282542	11.38	.717458	9
367	10.97	.992142	.40	.283225	11.37	.716775	8
025	10.93	.992118	.42	.283907	11.35	.716093	7
681	10.93	.992093	.40	.284588	11.33	.715412	6
337	10.90	9.992069	.42	9.285268	11.32	0.714732	5
991	10.90	.992044	.40	.285947	11.28	.714053	4
645	10.87	.992020	.40	.286624	11.28	.713376	3
297	10.85	.991996	.42	.287301	11.27	.712699	2
948	10.85	.991971	.40	.287977	11.25	.712023	1
599		9.991947		9.288652		0.711348	0
	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	

LOGARITHMIC SINES

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.
0	9.280599	10.82	9.991947	.42	9.288652	11.23	0.71134
1	.281248	10.82	.991922	.42	.289326	11.22	.71067
2	.281897	10.78	.991897	.40	.289999	11.20	.7100
3	.282544	10.77	.991873	.42	.290671	11.18	.70932
4	.283190	10.77	.991848	.42	.291342	11.18	.7086
5	9.283836	10.73	9.991823	.40	9.292013	11.15	0.7079
6	.284480	10.73	.991799	.42	.292682	11.13	.7073
7	.285124	10.70	.991774	.42	.293350	11.12	.7066
8	.285766	10.70	.991749	.42	.294017	11.12	.7059
9	.286408	10.67	.991724	.42	.294684	11.08	.7053
10	9.287048	10.67	9.991699	.42	9.295349	11.07	0.7046
11	.287688	10.63	.991674	.42	.296013	11.07	.7039
12	.288326	10.63	.991649	.42	.296677	11.03	.7033
13	.288964	10.60	.991624	.42	.297339	11.03	.7026
14	.289600	10.60	.991599	.42	.298001	11.02	.7019
15	9.290236	10.57	9.991574	.42	0.298662	11.00	0.7013
16	.290870	10.57	.991549	.42	.299322	10.97	.7006
17	.291504	10.55	.991524	.43	.299980	10.97	.7000
18	.292137	10.52	.991498	.42	.300638	10.95	.6993
19	.292768	10.52	.991473	.42	.301295	10.93	.6987
20	9.293399	10.50	9.991448	.43	9.301951	10.93	0.6980
21	.294029	10.48	.991422	.42	.302607	10.90	.6973
22	.294658	10.47	.991397	.42	.303261	10.88	.6967
23	.295286	10.45	.991372	.43	.303914	10.88	.6960
24	.295913	10.43	.991346	.42	.304567	10.85	.6954
25	9.296539	10.42	9.991321	.43	9.305218	10.85	0.6947
26	.297164	10.40	.991295	.42	.305869	10.83	.6941
27	.297788	10.40	.991270	.43	.306519	10.82	.6934
28	.298412	10.37	.991244	.43	.307168	10.80	.6928
29	.299034	10.35	.991218	.42	.307816	10.78	.6921
30	9.299655	10.35	9.991193	.43	9.308463	10.77	0.6915
31	.300276	10.32	.991167	.43	.309109	10.75	.6908
32	.300895	10.32	.991141	.43	.309754	10.75	.6902
33	.301514	10.30	.991115	.42	.310399	10.72	.6896
34	.302132	10.27	.991090	.43	.311042	10.72	.6889
35	9.302748	10.27	9.991064	.43	9.311685	10.70	0.6883
36	.303364	10.25	.991038	.43	.312327	10.68	.6876
37	.303979	10.23	.991012	.43	.312968	10.67	.6870
38	.304593	10.23	.990986	.43	.313608	10.65	.6863
39	.305207	10.20	.990960	.43	.314247	10.63	.6857
40	9.305819	10.18	9.990934	.43	9.314885	10.63	0.6851
41	.306430	10.18	.990908	.43	.315523	10.60	.6844
42	.307041	10.15	.990882	.45	.316159	10.60	.6838
43	.307650	10.15	.990855	.43	.316795	10.58	.6832
44	.308259	10.13	.990829	.43	.317430	10.57	.6825
45	9.308867	10.12	9.990803	.43	9.318064	10.55	0.6819
46	.309474	10.10	.990777	.45	.318697	10.55	.6813
47	.310080	10.08	.990750	.43	.319330	10.52	.6806
48	.310685	10.07	.990724	.45	.319961	10.52	.6800
49	.311289	10.07	.990697	.43	.320592	10.50	.6794
50	9.311893	10.03	9.990671	.43	9.321222	10.48	0.6787
51	.312495	10.03	.990645	.45	.321851	10.47	.6781
52	.313097	10.02	.990618	.45	.322479	10.45	.6775
53	.313698	9.98	.990591	.43	.323106	10.45	.6768
54	.314297	10.00	.990565	.45	.323733	10.42	.6762
55	9.314897	9.97	9.990538	.45	9.324358	10.42	0.6756
56	.315495	9.95	.990511	.43	.324983	10.40	.6750
57	.316092	9.95	.990485	.45	.325607	10.40	.6743
58	.316689	9.92	.990458	.45	.326231	10.37	.6737
59	.317284	9.92	.990431	.45	326853	10.37	.6731
60	9.317879		9.990404		9.327475		0.6725
	Cos.	D. 1".	Sin.	D 1".	Cot.	D. 1".	T

.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
379	9.90	9.990404	.43	9.327475	10.33	0.672525	60
473	9.88	.990378	.45	.328095	10.33	.671905	59
066	9.87	.990351	.45	.328715	10.32	.671285	58
658	9.85	.990324	.45	.329334	10.32	.670666	57
249	9.85	.990297	.45	.329953	10.28	.670047	56
840	9.83	9.990270	.45	9.330570	10.28	0.669430	55
430	9.82	.990243	.47	.331187	10.27	.668813	54
019	9.80	.990215	.45	.331803	10.25	.668197	53
607	9.78	.990188	.45	.332418	10.25	.667582	52
194	9.77	.990161	.45	.333033	10.22	.666967	51
780	9.77	9.990134	.45	9.333646	10.22	0.666354	50
366	9.73	.990107	47	.334259	10.20	.665741	49
950	9.73	.990079	.45	.334871	10.18	.665129	48
534	9.72	.990052	.45	.335482	10.18	.664518	47
117	9.72	.990025	.47	.336093	10.15	.663907	46
700	9.68	9.989997	.45	9.336702	10.15	0.663298	45
281	9.68	.989970	.47	.337311	10.13	.662689	44
862	9.67	.989942	.45	.337919	10.13	.662081	43
442	9.65	.989915	.47	.338527	10.10	.661473	42
021	9.63	.989887	.45	.339133	10.10	.660867	41
599	9.62	9.989860	.47	9.339739	10.08	0.660261	40
176	9.62	.989832	.47	.340344	10.07	.659656	39
753	9.60	.989804	.45	.340948	10.07	.659052	38
329	9.57	.989777	.47	.341552	10.05	.658448	37
903	9.58	.989749	.47	.342155	10.03	.657845	36
478	9.55	9.989721	.47	9.342757	10.03	0.657243	35
051	9.55	.989693	.47	.343358	10.00	.656642	34
624	9.52	.989665	.47	.343958	10.00	.656042	33
195	9.53	.989637	.45	.344558	9.98	.655442	32
767	9.50	.989610	.47	.345157	9.97	.654843	31
337	9.48	9.989582	.48	9.345755	9.97	0.654245	30
906	9.48	.989553	.47	.346353	9.93	.653647	29
475	9.47	.989525	.47	.346949	9.93	.653051	28
043	9.45	.989497	.47	.347545	9.93	.652455	27
610	9.43	.989469	.47	.348141	9.90	.651859	26
176	9.43	9.989441	.47	9.348735	9.90	0.651265	25
742	9.42	.989413	.47	.349329	9.88	.650671	24
307	9.40	.989385	.48	.349922	9.87	.650078	23
871	9.38	.989356	.47	.350514	9.87	.649486	22
434	9.37	.989328	.47	.351106	9.85	.648894	21
996	9.37	9.989300	.48	9.351697	9.83	0.648303	20
558	9.35	.989271	.47	.352287	9.82	.647713	19
119	9.33	.989243	.48	.352876	9.82	.647124	18
679	9.33	.989214	.47	.353465	9.80	.646535	17
239	9.30	.989186	.48	.354053	9.78	.645947	16
797	9.30	9.989157	.48	9.354640	9.78	0.645360	15
355	9.28	.989128	.47	.355227	9.77	.644773	14
912	9.28	.989100	.48	.355813	9.75	.644187	13
469	9.25	.989071	.48	.356398	9.73	.643602	12
024	9.25	.989042	.47	.356982	9.73	.643018	11
579	9.25	9.989014	.48	9.357566	9.72	0.642434	10
134	9.22	.988985	.48	.358149	9.70	.641851	9
687	9.22	.988956	.48	.358731	9.70	.641269	8
240	9.20	988927	.48	.359313	9.67	.640687	7
792	9.18	.988898	.48	.359893	9.68	.640107	6
343	9.17	9.988869	.48	9.360474	9.65	0.639526	5
893	9.17	.988840	.48	.361053	9.65	.638947	4
443	9.15	.988811	.48	.361632	9.63	.638368	3
992	9.13	.988782	.48	.362210	9.62	.637790	2
540	9.13	.988753	.48	.362787	9.62	.637213	1
088		9.988724		9.363364		0.636636	0
	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	

M	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.352088	9.12	9.988724	.48	9.363364	9.60	0.636636	60
1	.352635	9.10	.988695	.48	.363940	9.58	.636060	59
2	.353181	9.08	.988666	.50	.364515	9.58	.635485	58
3	.353726	9.08	.988636	.48	.365090	9.57	.634910	57
4	.354271	9.07	.988607	.48	.365664	9.55	.634336	56
5	9.354815	9.05	9.988578	.50	9.366237	9.55	0.633763	55
6	.355358	9.05	.988548	.48	.366810	9.53	.633190	54
7	.355901	9.03	.988519	.50	.367382	9.52	.632618	53
8	.356443	9.02	.988489	.48	.367953	9.52	.632047	52
9	.356984	9.00	.988460	.50	.368524	9.50	.631476	51
10	9.357524	9.00	9.988430	.48	9.369094	9.48	0.630906	50
11	.358064	8.98	.988401	.50	.369663	9.48	.630337	49
12	.358603	8.97	.988371	.48	.370232	9.45	.629768	48
13	.359141	8.95	.988342	.50	.370799	9.47	.629201	47
14	.359678	8.95	.988312	.50	.371367	9.43	.628633	46
15	9.360215	8.95	9.988282	.50	9.371933	9.43	0.628067	45
16	.360752	8.92	.988252	.48	.372499	9.42	.627501	44
17	.361287	8.92	.988223	.50	.373064	9.42	.626936	43
18	.361822	8.90	.988193	.50	.373629	9.40	.626371	42
19	.362356	8.88	.988163	.50	.374193	9.38	.625807	41
20	9.362889	8.88	9.988133	.50	9.374756	9.38	0.625244	40
21	.363422	8.87	.988103	.50	.375319	9.37	.624681	39
22	.363954	8.85	.988073	.50	.375881	9.35	.624119	38
23	.364485	8.85	.988043	.50	.376442	9.35	.623558	37
24	.365016	8.83	.988013	.50	.377003	9.33	.622997	36
25	9.365546	8.82	9.987983	.50	9.377563	9.32	0.622437	35
26	.366075	8.82	.987953	.52	.378122	9.32	.621878	34
27	.366604	8.78	.987922	.50	.378681	9.30	.621319	33
28	.367131	8.80	.987892	.50	.379239	9.30	.620761	32
29	.367659	8.77	.987862	.50	.379797	9.28	.620203	31
30	9.368185	8.77	9.987832	.52	9.380354	9.27	0.619646	30
31	.368711	8.75	.987801	.50	.380910	9.27	.619090	29
32	369236	8.75	.987771	.52	.381466	9.23	.618534	28
33	.369761	8.73	.987740	.50	.382020	9.25	.617980	27
34	.370285	8.72	.987710	.52	.382575	9.23	.617425	26
35	9.370808	8.70	9.987679	.50	9.383129	9.22	0.616871	25
36	.371330	8.70	.987649	.52	.383682	9.20	.616318	24
37	.371852	8.68	.987618	.50	.384234	9.20	.615766	23
38	.372373	8.68	.987588	.52	.384786	9.18	.615214	22
39	.372894	8.67	.987557	.52	.385337	9.18	.614663	21
40	9.373414	8.65	9.987526	.50	9.385888	9.17	0.614112	20
41	.373933	8.65	.987496	.52	.386438	9.15	.613562	19
42	.374452	8.63	.987465	.52	.386987	9.15	.613013	18
43	.374970	8.62	.987434	.52	.387536	9.13	.612464	17
44	.375487	8.60	.987403	.52	.388084	9.12	.611916	16
45	9.376003	8.60	9.987372	.52	9.388631	9.12	0.611369	15
46	.376519	8.60	.987341	.52	.389178	9.10	.610822	14
47	.377035	8.57	.987310	.52	.389724	9.10	.610276	13
48	.377549	8.57	.987279	.52	.390270	9.08	.609730	12
49	.378063	8.57	.987248	.52	.390815	9.08	.609185	11
50	9.378577	8.53	9.987217	.52	9.391360	9.05	0.608640	10
51	.379089	8.53	.987186	.52	.391903	9.07	.608097	9
52	.379601	8.53	.987155	.52	.392447	9.03	.607553	8
53	.380113	8.52	.987124	.53	.392989	9.03	.607011	7
54	.380624	8.50	.987092	.52	.393531	9.03	.606469	6
55	9.381134	8.48	9.987061	.52	9.394073	9.02	0.605927	5
56	.381643	8.48	.987030	.53	.394614	9.00	.605386	4
57	.382152	8.48	.986998	.52	.395154	9.00	.604846	3
58	.382661	8.45	.986967	.52	.395694	8.98	.604306	2
59	.383168	8.45	.986936	.53	.396233	8.97	.603767	1
60	9.383675		9.986904		9.396771		0.603229	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M

	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
5	8.45	9.986904	.52	9.396771	8.97	0.603229	60
2	8.42	.986873	.53	.397309	8.95	.602691	59
7	8.42	.986841	.53	.397846	8.95	.602154	58
2	8.42	.986809	.52	.398383	8.93	.601617	57
7	8.40	.986778	.53	.398919	8.93	.601081	56
1	8.38	9.986746	.53	9.399455	8.92	0.600545	55
4	8.38	.986714	.52	.399990	8.90	.600010	54
7	8.37	.986683	.53	.400524	8.90	.599476	53
9	8.35	.986651	.53	.401058	8.88	.598942	52
0	8.35	.986619	.53	.401591	8.88	.598409	51
1	8.33	9.986587	.53	9.402124	8.87	0.597876	50
1	8.33	.986555	.53	.402656	8.85	.597344	49
1	8.32	.986523	.53	.403187	8.85	.596813	48
0	8.30	.986491	.53	.403718	8.85	.596282	47
8	8.30	.986459	.53	.404249	8.82	.595751	46
6	8.28	9.986427	.53	9.404778	8.83	0.595222	45
3	8.27	.986395	.53	.405308	8.80	.594692	44
9	8.27	.986363	.53	.405836	8.80	.594164	43
5	8.27	.986331	.53	.406364	8.80	.593636	42
1	8.23	.986299	.55	.406892	8.78	.593108	41
5	8.23	9.986266	.53	9.407419	8.77	0.592581	40
9	8.23	.986234	.53	.407945	8.77	.592055	39
3	8.22	.986202	.55	.408471	8.75	.591529	38
6	8.20	.986169	.53	.408996	8.75	.591004	37
8	8.20	.986137	.55	.409521	8.73	.590479	36
0	8.18	9.986104	.53	9.410045	8.73	0.589955	35
1	8.18	.986072	.55	.410569	8.72	.589431	34
2	8.15	.986039	.53	.411092	8.72	.588908	33
1	8.17	.986007	.55	.411615	8.70	.588385	32
1	8.15	.985974	.53	.412137	8.68	.587863	31
0	8.13	9.985942	.55	9.412658	8.68	0.587342	30
2	8.12	.985909	.55	.413179	8.67	.586821	29
5	8.12	.985876	.55	.413699	8.67	.586301	28
2	8.12	.985843	.53	.414219	8.65	.585781	27
9	8.10	.985811	.55	.414738	8.65	.585262	26
5	8.08	9.985778	.55	9.415257	8.63	0.584743	25
0	8.08	.985745	.55	.415775	8.63	.584225	24
5	8.07	.985712	.55	.416293	8.62	.583707	23
9	8.05	.985679	.55	.416810	8.60	.583190	22
2	8.05	.985646	.55	.417326	8.60	.582674	21
5	8.05	9.985613	.55	9.417842	8.60	0.582158	20
8	8.03	.985580	.55	.418358	8.58	.581642	19
0	8.02	.985547	.55	.418873	8.57	.581127	18
1	8.02	.985514	.57	.419387	8.57	.580613	17
2	8.00	.985480	.55	.419901	8.57	.580099	16
2	7.98	9.985447	.55	9.420415	8.53	0.579585	15
1	7.98	.985414	.55	.420927	8.55	.579073	14
0	7.98	.985381	.57	.421440	8.53	.578560	13
9	7.97	.985347	.55	.421952	8.52	.578048	12
7	7.95	.985314	.57	.422463	8.52	.577537	11
4	7.95	9.985280	.55	9.422974	8.50	0.577026	10
1	7.93	.985247	.57	.423484	8.48	.576516	9
7	7.92	.985213	.55	.423993	8.50	.576007	8
2	7.92	.985180	.57	.424503	8.47	.575497	7
7	7.92	.985146	.55	.425011	8.47	.574989	6
2	7.90	9.985113	.57	9.425519	8.47	0.574481	5
6	7.88	.985079	.57	.426027	8.45	.573973	4
9	7.88	.985045	.57	.426534	8.45	.573466	3
2	7.87	.985011	.55	.427041	8.43	.572959	2
4	7.87	.984978	.57	.427547	8.42	.572453	1
6		9.984944		9.428052		0.571948	0
	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.
0	9.412996	7.85	9.984944	.57	9.428052	8.43	0.571948
1	.413467	7.85	.984910	.57	.428558	8.40	.571442
2	.413938	7.83	.984876	.57	.429062	8.40	.570938
3	.414408	7.83	.984842	.57	.429566	8.40	.570434
4	.414878	7.82	.984808	.57	.430070	8.38	.569930
5	9.415347	7.80	9.984774	.57	9.430573	8.37	0.569427
6	.415815	7.80	.984740	.57	.431075	8.37	.568925
7	.416283	7.80	.984706	.57	.431577	8.37	.568423
8	.416751	7.77	.984672	.57	.432079	8.35	.567921
9	.417217	7.78	.984638	.58	.432580	8.33	.567420
10	9.417684	7.77	9.984603	.57	9.433080	8.33	0.566920
11	.418150	7.75	.984569	.57	.433580	8.33	.566420
12	.418615	7.73	.984535	.58	.434080	8.32	.565920
13	.419079	7.75	.984500	.57	.434579	8.32	.565421
14	.419544	7.72	.984466	.57	.435078	8.30	.564922
15	9.420007	7.72	9.984432	.58	9.435576	8.28	0.564424
16	.420470	7.72	.984397	.57	.436073	8.28	.563927
17	.420933	7.70	.984363	.58	.436570	8.28	.563430
18	.421395	7.70	.984328	.57	.437067	8.27	.562933
19	.421857	7.68	.984294	.58	.437563	8.27	.562437
20	9.422318	7.67	9.984259	.58	9.438059	8.25	0.561941
21	.422778	7.67	.984224	.57	.438554	8.23	.561446
22	.423238	7.65	.914190	.58	.439048	8.25	.560952
23	.423697	7.65	.984155	.58	.439543	8.22	.560457
24	.424156	7.65	.984120	.58	.440036	8.22	.559964
25	9.424615	7.63	9.984085	.58	9.440529	8.22	0.559471
26	.425073	7.62	.984050	.58	.441022	8.20	.558978
27	.425530	7.62	.984015	.57	.441514	8.20	.558486
28	.425987	7.60	.983981	.58	.442006	8.18	.557994
29	.426443	7.60	.983946	.58	[illegible]	8.18	.557503
30	9.426899	7.58	9.983911	.60	9.442988	8.18	0.557012
31	.427354	7.58	.983875	.58	.443479	8.15	.556521
32	.427809	7.57	.983840	.58	.443968	8.17	.556032
33	.428263	7.57	.983805	.58	.444458	8.15	.555542
34	.428717	7.55	.983770	.58	.444947	8.13	.555053
35	9.429170	7.55	9.983735	.58	9.445435	8.13	0.554565
36	.429623	7.53	.983700	.60	.445923	8.13	.554077
37	.430075	7.53	.983664	.58	.446411	8.12	.553589
38	.430527	7.52	.983629	.58	.446898	8.10	.553102
39	.430978	7.52	.983594	.60	.447384	8.10	.552616
40	9.431429	7.50	9.983558	.58	9.447870	8.10	0.552130
41	.431879	7.50	.983523	.60	.448356	8.08	.551644
42	.432329	7.48	.983487	.58	.448841	8.08	.551159
43	.432778	7.47	.983452	.60	.449326	8.07	.550674
44	.433226	7.48	.983416	.58	.449810	8.07	.550190
45	9.433675	7.45	9.983381	.60	9.450294	8.05	0.549706
46	.434122	7.45	.983345	.60	.450777	8.05	.549223
47	.434569	7.45	.983309	.60	.451260	8.05	.548740
48	.435016	7.43	.983273	.58	.451743	8.03	.548257
49	.435462	7.43	.983238	.60	.452225	8.02	.547775
50	9.435908	7.42	9.983202	.60	9.452706	8.02	0.547294
51	.436353	7.42	.983166	.60	.453187	8.02	.546813
52	.436798	7.40	.983130	.60	.453668	8.00	.546332
53	.437242	7.40	.983094	.60	.454148	8.00	.545852
54	.437686	7.38	.983058	.60	.454628	7.98	.545372
55	9.438129	7.38	9.983022	.60	9.455107	7.98	0.544893
56	.438572	7.37	.982986	.60	.455586	7.97	.544414
57	.439014	7.37	.982950	.60	.456064	7.97	.543936
58	.439456	7.35	.982914	.60	.456542	7.95	.543458
59	.439897	7.35	.982878	.60	.457019	7.95	.542981
60	9.440338		9.982842		9.457496		0.542504
	Cos.	D. 1".	[illegible]	D. 1".	Cot.	D. 1".	Tan.

n.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0338	7.33	9.982842	.62	9.457496	7.95	0.542504	60
0778	7.33	.982805	.60	.457973	7.93	.542027	59
1218	7.33	.982769	.60	.458449	7.93	.541551	58
1658	7.30	.982733	.62	.458925	7.92	.541075	57
2096	7.32	.982696	.60	.459400	7.92	.540600	56
2535	7.30	9.982660	.60	9.459875	7.90	0.540125	55
2973	7.28	.982624	.62	.460349	7.90	.539651	54
3410	7.28	.982587	.60	.460823	7.90	.539177	53
3847	7.28	.982551	.62	.461297	7.88	.538703	52
4284	7.27	.982514	.62	.461770	7.87	.538230	51
4720	7.25	9.982477	.60	9.462242	7.88	0.537758	50
5155	7.25	.982441	.62	.462715	7.85	.537285	49
5590	7.25	.982404	.62	.463186	7.87	.536814	48
6025	7.23	.982367	.60	.463658	7.83	.536342	47
6459	7.23	.982331	.62	.464128	7.85	.535872	46
6893	7.22	9.982294	.62	9.464599	7.83	0.535401	45
7326	7.22	.982257	.62	.465069	7.83	.534931	44
7759	7.20	.982220	.62	.465539	7.82	.534461	43
8191	7.20	.982183	.62	.466008	7.82	.533992	42
8623	7.18	.982146	.62	.466477	7.80	.533523	41
9054	7.18	9.982109	.62	9.466945	7.80	0.533055	40
9485	7.17	.982072	.62	.467413	7.78	.532587	39
9915	7.17	.982035	.62	.467880	7.78	.532120	38
0345	7.17	.981998	.62	.468347	7.78	.531653	37
0775	7.15	.981961	.62	.468814	7.77	.531186	36
1204	7.13	9.981924	.63	9.469280	7.77	0.530720	35
1632	7.13	.981886	.62	.469746	7.75	.530254	34
2060	7.13	.981849	.62	.470211	7.75	.529789	33
[illegible]	7.12	.981812	.63	.470676	7.75	.529324	32
2915	7.12	.981774	.62	.471141	7.73	.528859	31
3342	7.10	9.981737	.62	9.471605	7.73	0.528395	30
3768	7.10	.981700	.63	.472069	7.72	.527931	29
4194	7.08	.981662	.62	.472532	7.72	.527468	28
4619	7.08	.981625	.63	.472995	7.70	.527005	27
5044	7.08	.981587	.63	.473457	7.70	.526543	26
5469	7.07	9.981549	.62	9.473919	7.70	0.526081	25
5893	7.05	.981512	.63	.474381	7.68	.525619	24
6316	7.05	.981474	.63	.474842	7.68	.525158	23
6739	7.05	.981436	.62	.475303	7.67	.524697	22
7162	7.03	.981399	.63	.475763	7.67	.524237	21
7584	7.03	9.981361	.63	9.476223	7.67	0.523777	20
8006	7.02	.981323	.63	.476683	7.65	.523317	19
8427	7.02	.981285	.63	.477142	7.65	.522858	18
8848	7.00	.981247	.63	.477601	7.63	.522399	17
9268	7.00	.981209	.63	.478059	7.63	.521941	16
9688	7.00	9.981171	.63	9.478517	7.63	0.521483	15
0108	6.98	.981133	.63	.478975	7.62	.521025	14
0527	6.98	.981095	.63	.479432	7.62	.520568	13
0946	6.97	.981057	.63	.479889	7.60	.520111	12
1364	6.97	.981019	.63	.480345	7.60	.519655	11
1782	6.95	9.980981	.65	9.480801	7.60	0.519199	10
2199	6.95	.980942	.63	.481257	7.58	.518743	9
2616	6.93	.980904	.63	.481712	7.58	.518288	8
3032	6.93	.980866	.65	.482167	7.57	.517833	7
3448	6.93	.980827	.63	.482621	7.57	.517379	6
3864	6.92	9.980789	.65	9.483075	7.57	0.516925	5
4279	6.92	.980750	.63	.483529	7.55	.516471	4
4694	6.90	.980712	.65	.483982	7.55	.516018	3
5108	6.90	.980673	.63	.484435	7.53	.515565	2
5522	6.88	.980635	.65	.484887	7.53	.515113	1
5935		9.980596		9.485339		0.514661	0
.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	C
0	9.465935	6.88	9.980596	.63	9.485339	7.53	0.5
1	.466348	6.88	.980558	.65	.485791	7.52	.5
2	.466761	6.87	.980519	.65	.486242	7.52	.5
3	.467173	6.87	.980480	.63	.486693	7.50	.5
4	.467585	6.85	.980442	.65	.487143	7.50	.5
5	9.467996	6.85	9.980403	.65	9.487593	7.50	0.5
6	.468407	6.83	.980364	.65	.488043	7.48	.5
7	.468817	6.83	.980325	.65	.488492	7.48	.5
8	.469227	6.83	.980286	.65	.488941	7.48	.5
9	.469637	6.82	.980247	.65	.489390	7.47	.5
10	9.470046	6.82	9.980208	.65	9.489838	7.47	0.5
11	.470455	6.80	.980169	.65	.490286	7.45	.5
12	.470863	6.80	.980130	.65	.490733	7.45	.5
13	.471271	6.80	.980091	.65	.491180	7.45	.5
14	.471679	6.78	.980052	.67	.491627	7.43	.5
15	9.472086	6.77	9.980012	.65	9.492073	7.43	0.5
16	.472492	6.77	.979973	.65	.492519	7.43	.5
17	.472898	6.77	.979934	.65	.492965	7.42	.5
18	.473304	6.77	.979895	.67	.493410	7.40	.5
19	.473710	6.75	.979855	.65	.493854	7.42	.5
20	9.474115	6.73	9.979816	.67	9.494299	7.40	0.5
21	.474519	6.73	.979776	.65	.494743	7.38	.5
22	.474923	6.73	.979737	.67	.495186	7.40	.5
23	.475327	6.72	.979697	.65	.495630	7.38	.5
24	.475730	6.72	.979658	.67	.496073	7.37	.5
25	9.476133	6.72	9.979618	.65	9.496515	7.37	0.5
26	.476536	6.70	.979579	.67	.496957	7.37	.5
27	.476938	6.70	.979539	.67	.497399	7.37	.5
28	.477340	6.68	.979499	.67	.497841	7.35	.5
29	.477741	6.68	.979459	.65	.498282	7.33	.5
30	9.478142	6.67	9.979420	.67	9.498722	7.35	0.5
31	.478542	6.67	.979380	.67	.499163	7.33	.5
32	.478942	6.67	.979340	.67	.499603	7.32	.5
33	.479342	6.65	.979300	.67	.500042	7.32	.4
34	.479741	6.65	.979260	.67	.500481	7.32	.4
35	9.480140	6.65	9.979220	.67	9.500920	7.32	0.4
36	.480539	6.63	.979180	.67	.501359	7.30	.4
37	.480937	6.62	.979140	.67	.501797	7.30	.4
38	.481334	6.62	.979100	.68	.502235	7.28	.4
39	.481731	6.62	.979059	.67	.502672	7.28	.4
40	9.482128	6.62	9.979019	.67	9.503109	7.28	0.4
41	.482525	6.60	.978979	.67	.503546	7.27	.4
42	.482921	6.58	.978939	.68	.503982	7.27	.4
43	.483316	6.60	.978898	.67	.504418	7.27	.4
44	.483712	6.58	.978858	.68	.504854	7.25	.4
45	9.484107	6.57	9.978817	.67	9.505289	7.25	0.4
46	.484501	6.57	.978777	.67	.505724	7.25	.4
47	.484895	6.57	.978737	.68	.506159	7.23	.4
48	.485289	6.55	.978696	.68	.506593	7.23	.4
49	.485682	6.55	.978655	.67	.507027	7.22	.4
50	9.486075	6.53	9.978615	.68	9.507460	7.22	0.4
51	.486467	6.55	.978574	.68	.507893	7.22	.4
52	.486860	6.52	.978533	.67	.508326	7.22	.4
53	.487251	6.53	.978493	.68	.508759	7.20	.4
54	.487643	6.52	.978452	.68	.509191	7.18	.4
55	9.488034	6.50	9.978411	.68	9.509622	7.20	0.4
56	.488424	6.50	.978370	.68	.510054	7.18	.4
57	.488814	6.50	.978329	.68	.510485	7.18	.4
58	.489204	6.48	.978288	.68	.510916	7.17	.4
59	.489593	6.48	.978247	.68	.511346	7.17	.4
60	9.489982		9.978206		9.511776		0.
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.489982	6.48	9.978206	.68	9.511776	7.17	0.488224	60
1	.490371	6.47	.978165	.68	.512206	7.15	.487794	59
2	.490759	6.47	.978124	.68	.512635	7.15	.487365	58
3	.491147	6.47	.978083	.68	.513064	7.15	.486936	57
4	.491535	6.45	.978042	.68	.513493	7.13	.486507	56
5	9.491922	6.43	9.978001	.70	9.513921	7.13	0.486079	55
6	.492308	6.45	.977959	.68	.514349	7.13	.485651	54
7	.492695	6.43	.977918	.68	.514777	7.12	.485223	53
8	.493081	6.42	.977877	.70	.515204	7.12	.484796	52
9	.493466	6.42	.977835	.68	.515631	7.10	.484369	51
10	9.493851	6.42	9.977794	.70	9.516057	7.12	0.483943	50
11	.494236	6.42	.977752	.68	.516484	7.10	.483516	49
12	.494621	6.40	.977711	.70	.516910	7.08	.483090	48
13	.495005	6.38	.977669	.68	.517335	7.10	.482665	47
14	.495388	6.40	.977628	.70	.517761	7.08	.482239	46
15	9.495772	6.37	9.977586	.70	9.518186	7.07	0.481814	45
16	.496154	6.38	.977544	.68	.518610	7.07	.481390	44
17	.496537	6.37	.977503	.70	.519034	7.07	.480966	43
18	.496919	6.37	.977461	.70	.519459	7.07	.480541	42
19	.497301	6.35	.977419	.70	.519882	7.05	.480118	41
20	9.497682	6.37	9.977377	.70	9.520305	7.05	0.479695	40
21	.498064	6.33	.977335	.70	.520728	7.05	.479272	39
22	.498444	6.35	.977293	.70	.521151	7.03	.478849	38
23	.498825	6.32	.977251	.70	.521573	7.03	.478427	37
24	.499204	6.33	.977209	.70	.521995	7.03	.478005	36
25	9.499584	6.32	9.977167	.70	9.522417	7.02	0.477583	35
26	.499963	6.32	.977125	.70	.522838	7.02	.477162	34
27	.500342	6.32	.977083	.70	.523259	7.02	.476741	33
28	.500721	6.30	.977041	.70	.523680	7.00	.476320	32
29	.501099	6.28	.976999	.70	.524100	7.00	.475900	31
30	9.501476	6.30	9.976957	.72	9.524520	7.00	0.475480	30
31	.501854	6.28	.976914	.70	.524940	6.98	.475060	29
32	.502231	6.27	.976872	.70	.525359	6.98	.474641	28
33	.502607	6.28	.976830	.72	.525778	6.98	.474222	27
34	.502984	6.27	.976787	.70	.526197	6.97	.473803	26
35	9.503360	6.25	9.976745	.72	9.526615	6.97	0.473385	25
36	.503735	6.25	.976702	.70	.527033	6.97	.472967	24
37	.504110	6.25	.976660	.72	.527451	6.95	.472549	23
38	.504485	6.25	.976617	.72	.527868	6.95	.472132	22
39	.504860	6.23	.976574	.70	.528285	6.95	.471715	21
40	9.505234	6.23	9.976532	.72	9.528702	6.95	0.471298	20
41	.505608	6.22	.976489	.72	.529119	6.93	.470881	19
42	.505981	6.22	.976446	.70	.529535	6.93	.470465	18
43	.506354	6.22	.976404	.72	.529951	6.92	.470049	17
44	.506727	6.20	.976361	.72	.530366	6.92	.469634	16
45	9.507099	6.20	9.976318	.72	9.530781	6.92	0.469219	15
46	.507471	6.20	.976275	.72	.531196	6.92	.468804	14
47	.507843	6.18	.976232	.72	.531611	6.90	.468389	13
48	.508214	6.18	.976189	.72	.532025	6.90	.467975	12
49	.508585	6.18	.976146	.72	.532439	6.90	.467561	11
50	9.508956	6.17	9.976103	.72	9.532853	6.88	0.467147	10
51	.509326	6.17	.976060	.72	.533266	6.88	.466734	9
52	.509696	6.15	.976017	.72	.533679	6.88	.466321	8
53	.510065	6.15	.975974	.73	.534092	6.87	.465908	7
54	.510434	6.15	.975930	.72	.534504	6.87	.465496	6
55	9.510803	6.15	9.975887	.72	9.534916	6.87	0.465084	5
56	.511172	6.13	.975844	.73	.535328	6.85	.464672	4
57	.511540	6.12	.975800	.72	.535739	6.85	.464261	3
58	.511907	6.13	.975757	.72	.536150	6.85	.463850	2
59	.512275	6.12	.975714	.73	.536561	6.85	.463439	1
60	9.512642		9.975670		9.536972		0.463028	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.512642	6.12	9.975670	.72	9.536972	6.83	0.463028	60
1	.513009	6.10	.975627	.73	.537382	6.83	.462618	59
2	.513375	6.10	.975583	.73	.537792	6.83	.462208	58
3	.513741	6.10	.975539	.72	.538202	6.82	.461798	57
4	.514107	6.08	.975496	.73	.538611	6.82	.461389	56
5	9.514472	6.08	9.975452	.73	9.539020	6.82	0.460980	55
6	.514837	6.08	.975408	.72	.539429	6.80	.460571	54
7	.515202	6.07	.975365	.73	.539837	6.80	.460163	53
8	.515566	6.07	.975321	.73	.540245	6.80	.459755	52
9	.515930	6.07	.975277	.73	.540653	6.80	.459347	51
10	9.516294	6.05	9.975233	.73	9.541061	6.78	0.458939	50
11	.516657	6.05	.975189	.73	.541468	6.78	.458532	49
12	.517020	6.03	.975145	.73	.541875	6.77	.458125	48
13	.517382	6.05	.975101	.73	.542281	6.78	.457719	47
14	.517745	6.03	.975057	.73	.542688	6.77	.457312	46
15	9.518107	6.02	9.975013	.73	9.543094	6.75	0.456906	45
16	.518468	6.02	.974969	.73	.543499	6.77	.456501	44
17	.518829	6.02	.974925	.75	.543905	6.75	.456095	43
18	.519190	6.02	.974880	.73	.544310	6.75	.455690	42
19	.519551	6.00	.974836	.73	.544715	6.73	.455285	41
20	9.519911	6.00	9.974792	.73	9.545119	6.75	0.454881	40
21	.520271	6.00	.974748	.75	.545524	6.73	.454476	39
22	.520631	5.98	.974703	.73	.545928	6.72	.454072	38
23	.520990	5.98	.974659	.75	.546331	6.73	.453669	37
24	.521349	5.97	.974614	.73	.546735	6.72	.453265	36
25	9.521707	5.98	9.974570	.75	9.547138	6.70	0.452862	35
26	.522066	5.97	.974525	.73	.547540	6.72	.452460	34
27	.522424	5.95	.974481	.75	.547943	6.70	.452057	33
28	.522781	5.95	.974436	.75	.548345	6.70	.451655	32
29	.523138	5.95	.974391	.73	.548747	6.70	.451253	31
30	9.523495	5.95	9.974347	.75	9.549149	6.68	0.450851	30
31	.523852	5.93	.974302	.75	.549550	6.68	.450450	29
32	.524208	5.93	.974257	.75	.549951	6.68	.450049	28
33	.524564	5.93	.974212	.75	.550352	6.67	.449648	27
34	.524920	5.92	.974167	.75	.550752	6.68	.449248	26
35	9.525275	5.92	9.974122	.75	9.551153	6.65	0.448847	25
36	.525630	5.90	.974077	.75	.551552	6.67	.448448	24
37	.525984	5.92	.974032	.75	.551952	6.65	.448048	23
38	.526339	5.90	.973987	.75	.552351	6.65	.447649	22
39	.526693	5.88	.973942	.75	.552750	6.65	.447250	21
40	9.527046	5.90	9.973897	.75	9.553149	6.65	0.446851	20
41	.527400	5.88	.973852	.75	.553548	6.63	.446452	19
42	.527753	5.87	.973807	.77	.553946	6.63	.446054	18
43	.528105	5.88	.973761	.75	.554344	6.63	.445656	17
44	.528458	5.87	.973716	.75	.554741	6.63	.445259	16
45	9.528810	5.85	9.973671	.77	9.555139	6.62	0.444861	15
46	.529161	5.87	.973625	.75	.555536	6.62	.444464	14
47	.529513	5.85	.973580	.75	.555933	6.60	.444067	13
48	.529864	5.85	.973535	.77	.556329	6.60	.443671	12
49	.530215	5.83	.973489	.75	.556725	6.60	.443275	11
50	9.530565	5.83	9.973444	.77	9.557121	6.60	0.442879	10
51	.530915	5.83	.973398	.77	.557517	6.60	.442483	9
52	.531265	5.82	.973352	.75	.557913	6.59	.442087	8
53	.531614	5.82	.973307	.77	.558309	6.58	.441692	7
54	.531963	5.82	.973261	.77	.558703	6.57	.441297	6
55	9.532312	5.82	9.973215	.77	9.559097	6.57	0.440903	5
56	.532661	5.80	.973169	.75	.559491	6.57	.440509	4
57	.533009	5.80	.973124	.77	.559885	6.57	.440115	3
58	.533357	5.78	.973078	.77	.560279	6.57	.439721	2
59	.533704	5.80	.973032	.77	.560673	6.55	.439327	1
60	9.534052		9.972986		9.561066		0.438934	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
9.534052	5.78	9.972986	.77	9.561066	6.55	0.438934	60
.534399	5.77	.972940	.77	.561459	6.53	.438541	59
.534745	5.78	.972894	.77	.561851	6.55	.438149	58
.535092	5.77	.972848	.77	.562244	6.53	.437756	57
.535438	5.75	.972802	.78	.562636	6.53	.437364	56
9.535783	5.77	9.972755	.77	9.563028	6.52	0.436972	55
.536129	5.75	.972709	.77	.563419	6.53	.436581	54
.536474	5.73	.972663	.77	.563811	6.52	.436189	53
.536818	5.75	.972617	.78	.564202	6.52	.435798	52
.537163	5.73	.972570	.77	.564593	6.50	.435407	51
9.537507	5.73	9.972524	.77	9.564983	6.50	0.435017	50
.537851	5.72	.972478	.78	.565373	6.50	.434627	49
.538194	5.73	.972431	.77	.565763	6.50	.434237	48
.538538	5.70	.972385	.78	.566153	6.48	.433847	47
.538880	5.72	.972338	.78	.566542	6.50	.433458	46
9.539223	5.70	9.972291	.77	9.566932	6.47	0.433068	45
.539565	5.70	.972245	.78	.567320	6.48	.432680	44
.539907	5.70	.972198	.78	.567709	6.48	.432291	43
.540249	5.68	.972151	.77	.568098	6.47	.431902	42
.540590	5.68	.972105	.78	.568486	6.45	.431514	41
9.540931	5.68	9.972058	.78	9.568873	6.47	0.431127	40
.541272	5.68	.972011	.78	.569261	6.45	.430739	39
.541613	5.67	.971964	.78	.569648	6.45	.430352	38
.541953	5.67	.971917	.78	.570035	6.45	.429965	37
.542293	5.65	.971870	.78	.570422	6.45	.429578	36
9.542632	5.65	9.971823	.78	9.570809	6.43	0.429191	35
.542971	5.65	.971776	.78	.571195	6.43	.428805	34
.543310	5.65	.971729	.78	.571581	6.43	.428419	33
.543649	5.63	.971682	.78	.571967	6.42	.428033	32
.543987	5.63	.971635	.78	.572352	6.43	.427648	31
9.544325	5.63	9.971588	.80	9.572738	6.42	0.427262	30
.544663	5.62	.971540	.78	.573123	6.40	.426877	29
.545000	5.63	.971493	.78	.573507	6.42	.426493	28
.545338	5.60	.971446	.80	.573892	6.40	.426108	27
.545674	5.62	.971398	.78	.574276	6.40	.425724	26
9.546011	5.60	9.971351	.80	9.574660	6.40	0.425340	25
.546347	5.60	.971303	.78	.575044	6.38	.424956	24
.546683	5.60	.971256	.80	.575427	6.38	.424573	23
.547019	5.58	.971208	.78	.575810	6.38	.424190	22
.547354	5.58	.971161	.80	.576193	6.38	.423807	21
9.547689	5.58	9.971113	.78	9.576576	6.38	0.423424	20
.548024	5.58	.971066	.80	.576959	6.37	.423041	19
.548359	5.57	.971018	.80	.577341	6.37	.422659	18
.548693	5.57	.970970	.80	.577723	6.35	.422277	17
.549027	5.55	.970922	.80	.578104	6.37	.421896	16
9.549360	5.55	9.970874	.78	9.578486	6.35	0.421514	15
.549693	5.55	.970827	.80	.578867	6.35	.421133	14
.550026	5.55	.970779	.80	.579248	6.35	.420752	13
.550359	5.55	.970731	.80	.579629	6.33	.420371	12
.550692	5.53	.970683	.80	.580009	6.33	.419991	11
9.551024	5.53	9.970635	.82	9.580389	6.33	0.419611	10
.551356	5.52	.970586	.80	.580769	6.33	.419231	9
.551687	5.52	.970538	.80	.581149	6.32	.418851	8
.552018	5.52	.970490	.80	.581528	6.32	.418472	7
.552349	5.52	.970442	.80	.581907	6.32	.418093	6
9.552680	5.50	9.970394	.82	9.582286	6.32	0.417714	5
.553010	5.52	.970345	.80	.582665	6.32	.417335	4
.553341	5.48	.970297	.80	.583044	6.30	.416956	3
.553670	5.50	.970249	.82	.583422	6.30	.416578	2
.554000	5.48	.970200	.80	.583800	6.28	.416200	1
9.554329		9.970152		9.584177		0.415823	0
Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.591878	4.97	9.964026	.90	9.627852	5.85	0.372148	60
1	.592176	4.95	.963972	.88	.628203	5.85	.371797	59
2	.592473	4.95	.963919	.90	.628554	5.85	.371446	58
3	.592770	4.95	.963865	.90	.628905	5.83	.371095	57
4	.593067	4.93	.963811	.90	.629255	5.85	.370745	56
5	9.593363	4.93	9.963757	.88	9.629606	5.83	0.370394	55
6	.593659	4.93	.963704	.90	.629956	5.83	.370044	54
7	.593955	4.93	.963650	.90	.630306	5.83	.369694	53
8	.594251	4.93	.963596	.90	.630656	5.82	.369344	52
9	.594547	4.92	.963542	.90	.631005	5.83	.368995	51
10	9.594842	4.92	9.963488	.90	9.631355	5.82	0.368645	50
11	.595137	4.92	.963434	.92	.631704	5.82	.368296	49
12	.595432	4.92	.963379	.90	.632053	5.82	.367947	48
13	.595727	4.90	.963325	.90	.632402	5.80	.367598	47
14	.596021	4.90	.963271	.90	.632750	5.82	.367250	46
15	9.596315	4.90	9.963217	.90	9.633099	5.80	0.366901	45
16	.596609	4.90	.963163	.92	.633447	5.80	.366553	44
17	.596903	4.88	.963108	.90	.633795	5.80	.366205	43
18	.597196	4.90	.963054	.92	.634143	5.78	.365857	42
19	.597490	4.88	.962999	.90	.634490	5.80	.365510	41
20	9.597783	4.87	9.962945	.92	9.634838	5.78	0.365162	40
21	.598075	4.88	.962890	.90	.635185	5.78	.364815	39
22	.598368	4.87	.962836	.92	.635532	5.78	.364468	38
23	.598660	4.87	.962781	.90	.635879	5.78	.364121	37
24	.598952	4.87	.962727	.92	.636226	5.77	.363774	36
25	9.599244	4.87	9.962672	.92	9.636572	5.78	0.363428	35
26	.599536	4.85	.962617	.92	.636919	5.77	.363081	34
27	.599827	4.85	.962562	.90	.637265	5.77	.362735	33
28	.600118	4.85	.962508	.92	.637611	5.75	.362389	32
29	.600409	4.85	.962453	.92	.637956	5.77	.362044	31
30	9.600700	4.83	9.962398	.92	9.638302	5.75	0.361698	30
31	.600990	4.83	.962343	.92	.638647	5.75	.361353	29
32	.601280	4.83	.962288	.92	.638992	5.75	.361008	28
33	.601570	4.83	.962233	.92	.639337	5.75	.360663	27
34	.601860	4.83	.962178	.92	.639682	5.75	.360318	26
35	9.602150	4.82	9.962123	.93	9.640027	5.73	0.359973	25
36	.602439	4.82	.962067	.92	.640371	5.75	.359629	24
37	.602728	4.82	.962012	.92	.640716	5.73	.359284	23
38	.603017	4.80	.961957	.92	.641060	5.73	.358940	22
39	.603305	4.82	.961902	.93	.641404	5.72	.358596	21
40	9.603594	4.80	9.961846	.92	9.641747	5.73	0.358253	20
41	.603882	4.80	.961791	.93	.642091	5.72	.357909	19
42	.604170	4.78	.961735	.92	.642434	5.72	.357566	18
43	.604457	4.80	.961680	.93	.642777	5.72	.357223	17
44	.604745	4.78	.961624	.92	.643120	5.72	.356880	16
45	9.605032	4.78	9.961569	.93	9.643463	5.72	0.356537	15
46	.605319	4.78	.961513	.92	.643806	5.70	.356194	14
47	.605606	4.77	.961458	.93	.644148	5.70	.355852	13
48	.605892	4.78	.961402	.93	.644490	5.70	.355510	12
49	.606179	4.77	.961346	.93	.644832	5.70	.355168	11
50	9.606465	4.77	9.961290	.92	9.645174	5.70	0.354826	10
51	.606751	4.75	.961235	.93	.645516	5.68	.354484	9
52	.607036	4.77	.961179	.93	.645857	5.70	.354143	8
53	.607322	4.75	.961123	.93	.646199	5.68	.353801	7
54	.607607	4.75	.961067	.93	.646540	5.68	.353460	6
55	9.607892	4.75	9.961011	.93	9.646881	5.68	0.353119	5
56	.608177	4.73	.960955	.93	.647222	5.67	.352778	4
57	.608461	4.73	.960899	.93	.647562	5.68	.352438	3
58	.608745	4.73	.960843	.95	.647903	5.67	.352097	2
59	.609029	4.73	.960786	.93	.648243	5.67	.351757	1
60	9.609313		9.960730		9.648583		0.351417	0
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	M.

Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
9.573575	5.22	9.967166	.85	9.606410	6.05	0.393590	60
.573888	5.20	.967115	.85	.606773	6.07	.393227	59
.574200	5.20	.967064	.85	.607137	6.05	.392863	58
.574512	5.20	.967013	.87	.607500	6.05	.392500	57
.574824	5.20	.966961	.85	.607863	6.03	.392137	56
9.575136	5.18	9.966910	.85	9.608225	6.05	0.391775	55
.575447	5.18	.966859	.85	.608588	6.03	.391412	54
.575758	5.18	.966808	.87	.608950	6.03	.391050	53
.576069	5.17	.966756	.85	.609312	6.03	.390688	52
.576379	5.17	.966705	.87	.609674	6.03	.390326	51
9.576689	5.17	9.966653	.85	9.610036	6.02	0.389964	50
.576999	5.17	.966602	.87	.610397	6.03	.389603	49
.577309	5.15	.966550	.85	.610759	6.02	.389241	48
.577618	5.15	.966499	.87	.611120	6.00	.388880	47
.577927	5.15	.966447	.87	.611480	6.02	.388520	46
9.578236	5.15	9.966395	.85	9.611841	6.00	0.388159	45
.578545	5.13	.966344	.87	.612201	6.00	.387799	44
.578853	5.15	.966292	.87	.612561	6.00	.387439	43
.579162	5.13	.966240	.87	.612921	6.00	.387079	42
.579470	5.12	.966188	.87	.613281	6.00	.386719	41
9.579777	5.13	9.966136	.85	9.613641	5.98	0.386359	40
.580085	5.12	.966085	.87	.614000	5.98	.386000	39
.580392	5.12	.966033	.87	.614359	5.98	.385641	38
.580699	5.10	.965981	.87	.614718	5.98	.385282	37
.581005	5.12	.965929	.88	.615077	5.97	.384923	36
9.581312	5.10	9.965876	.87	9.615435	5.97	0.384565	35
.581618	5.10	.965824	.87	.615793	5.97	.384207	34
.581924	5.08	.965772	.87	.616151	5.97	.383849	33
.582229	5.10	.965720	.87	.616509	5.97	.383491	32
.582535	5.08	.965668	.88	.616867	5.95	.383133	31
9.582840	5.08	9.965615	.87	9.617224	5.97	0.382776	30
.583145	5.07	.965563	.87	.617582	5.95	.382418	29
.583449	5.08	.965511	.88	.617939	5.93	.382061	28
.583754	5.07	.965458	.87	.618295	5.95	.381705	27
.584058	5.05	.965406	.88	.618652	5.93	.381348	26
9.584361	5.07	9.965353	.87	9.619008	5.93	0.380992	25
.584665	5.05	.965301	.88	.619364	5.93	.380636	24
.584968	5.07	.965248	.88	.619720	5.93	.380280	23
.585272	5.03	.965195	.87	.620076	5.93	.379924	22
.585574	5.05	.965143	.88	.620432	5.92	.379568	21
9.585877	5.03	9.965090	.88	9.620787	5.92	0.379213	20
.586179	5.05	.965037	.88	.621142	5.92	.378858	19
.586482	5.02	.964984	.88	.621497	5.92	.378503	18
.586783	5.03	.964931	.87	.621852	5.92	.378148	17
.587085	5.02	.964879	.88	.622207	5.90	.377793	16
9.587386	5.03	9.964826	.88	9.622561	5.90	0.377439	15
.587688	5.02	.964773	.88	.622915	5.90	.377085	14
.587989	5.00	.964720	.90	.623269	5.90	.376731	13
.588289	5.02	.964666	.88	.623623	5.88	.376377	12
.588590	5.00	.964613	.88	.623976	5.90	.376024	11
9.588890	5.00	9.964560	.88	9.624330	5.88	0.375670	10
.589190	4.98	.964507	.88	.624683	5.88	.375317	9
.589489	5.00	.964454	.90	.625036	5.87	.374964	8
.589789	4.98	.964400	.88	.625388	5.88	.374612	7
.590088	4.98	.964347	.88	.625741	5.87	.374259	6
9.590387	4.98	9.964294	.90	9.626093	5.87	0.373907	5
.590686	4.97	.964240	.88	.626445	5.87	.373555	4
.590984	4.97	.964187	.90	.626797	5.87	.373203	3
.591282	4.97	.964133	.88	.627149	5.87	.372851	2
.591580	4.97	.964080	.90	.627501	5.85	.372499	1
9.591878		9.964026		9.627852		0.372148	0
Cos.	D. 1″.	Sin.	D. 1″	Cot.	D. 1″.	Tan.	M.

LOGARITHMIC SINES

M.	Sin.	D. 1″.	Cos.	D. 1″	Tan.	D. 1″.	Cot.
0	9.591878	4.97	9.964026	.90	9.627852	5.85	0.37214
1	.592176	4.95	.963972	.88	.628203	5.85	.37179
2	.592473	4.95	.963919	.90	.628554	5.85	.37144
3	.592770	4.95	.963865	.90	.628905	5.83	.37109
4	.593067	4.93	.963811	.90	.629255	5.85	.37074
5	9.593363	4.93	9.963757	.88	9.629606	5.83	0.37039
6	.593659	4.93	.963704	.90	.629956	5.83	.37004
7	.593955	4.93	.963650	.90	.630306	5.83	.36969
8	.594251	4.93	.963596	.90	.630656	5.82	.36934
9	.594547	4.92	.963542	.90	.631005	5.83	.36899
10	9.594842	4.92	9.963488	.90	9.631355	5.82	0.36864
11	.595137	4.92	.963434	.92	.631704	5.82	.36829
12	.595432	4.92	.963379	.90	.632053	5.82	.36794
13	.595727	4.90	.963325	.90	.632402	5.80	.36759
14	.596021	4.90	.963271	.90	.632750	5.82	.36725
15	9.596315	4.90	9.963217	.90	9.633099	5.80	0.36690
16	.596609	4.90	.963163	.92	.633447	5.80	.36655
17	.596903	4.88	.963108	.90	.633795	5.80	.36620
18	.597196	4.90	.963054	.92	.634143	5.78	.36585
19	.597490	4.88	.962999	.90	.634490	5.80	.36551
20	9.597783	4.87	9.962945	.92	9.634838	5.78	0.36516
21	.598075	4.88	.962890	.90	.635185	5.78	.36481
22	.598368	4.87	.962836	.92	.635532	5.78	.36446
23	.598660	4.87	.962781	90	.635879	5.78	.36412
24	.598952	4.87	.962727	.92	.636226	5.77	.36377
25	9.599244	4.87	9.962672	.92	9.636572	5.78	0.36342
26	.599536	4.85	.962617	.92	.636919	5.77	.36308
27	.599827	4.85	.962562	.90	.637265	5.77	.36273
28	.600118	4.85	.962508	.92	.637611	5.75	.36238
29	.600409	4.85	.962453	.92	.637956	5.77	.36204
30	9.600700	4.83	9.962398	.92	9.638302	5.75	0.36169
31	.600990	4.83	.962343	.92	.638647	5.75	.36135
32	.601280	4.83	.962288	.92	.638992	5.75	.36100
33	.601570	4.83	.962233	.92	.639337	5.75	.36066
34	.601860	4.83	.962178	.92	.639682	5.75	.36031
35	9.602150	4.82	9.962123	.93	9.640027	5.73	0.35997
36	.602439	4.82	.962067	.92	.640371	5.75	.35962
37	.602728	4.82	.962012	.92	.640716	5.73	.35928
38	.603017	4.80	.961957	.92	.641060	5.73	.35894
39	.603305	4.82	.961902	.93	.641404	5.72	.35859
40	9.603594	4.80	9.961846	.92	9.641747	5.73	0.35825
41	.603882	4.80	.961791	.93	.642091	5.72	.35790
42	.604170	4.78	.961735	.92	.642434	5.72	.35756
43	604457	4.80	.961680	.93	.642777	5.72	.35722
44	.604745	4.78	.961624	.92	.643120	5.72	.35688
45	9.605032	4.78	9.961569	.93	9.643463	5.72	0.35653
46	.605319	4.78	.961513	.92	.643806	5.70	.35619
47	.605606	4.77	.961458	.93	.644148	5.70	.35585
48	.605892	4.78	.961402	.93	.644490	5.70	.35551
49	.606179	4.77	.961346	.93	.644832	5.70	.35516
50	9.606465	4.77	9.961290	.92	9.645174	5.70	0.35482
51	.606751	4.75	.961235	.93	.645516	5.68	.35448
52	.607036	4.77	.961179	.93	.645857	5.70	.35414
53	.607322	4.75	.961123	.93	.646199	5.68	.35380
54	.607607	4.75	.961067	.93	.646540	5.68	.35346
55	9.607892	4.75	9.961011	.93	9.646881	5.68	0.35311
56	.608177	4.73	.960955	.93	.647222	5.67	.35277
57	.608461	4.73	.960899	.93	.647562	5.68	.35243
58	.608745	4.73	.960843	.95	.647903	5.67	.35209
59	.609029	4.73	.960786	.93	.648243	5.67	.35175
60	9.609313		9.960730		9.648583		0.35141
	Cos.	D. 1″.	Sin.	D. 1″	Cot.	D. 1″.	Tan.

Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
9.609313	4.73	9.960730	.93	9.648583	5.67	0.351417	60
.609597	4.72	.960674	.93	.648923	5.67	.351077	59
.609880	4.73	.960618	.95	.649263	5.65	.350737	58
.610164	4.72	.960561	.93	.649602	5.67	.350398	57
.610447	4.70	.960505	.95	.649942	5.65	.350058	56
9.610729	4.72	9.960448	.93	9.650281	5.65	0.349719	55
.611012	4.70	.960392	.95	.650620	5.65	.349380	54
.611294	4.70	.960335	.93	.650959	5.63	.349041	53
.611576	4.70	.960279	.95	.651297	5.65	.348703	52
.611858	4.70	.960222	.95	.651636	5.65	.348364	51
9.612140	4.68	9.960165	.93	9.651974	5.63	0.348026	50
.612421	4.68	.960109	.95	.652312	5.63	.347688	49
.612702	4.68	.960052	.95	.652650	5.63	.347350	48
.612983	4.68	.959995	.95	.652988	5.63	.347012	47
.613264	4.68	.959938	.93	.653326	5.62	.346674	46
9.613545	4.67	9.959882	.95	9.653663	5.62	0.346337	45
.613825	4.67	.959825	.95	.654000	5.62	.346000	44
.614105	4.67	.959768	.95	.654337	5.62	.345663	43
.614385	4.67	.959711	.95	.654674	5.62	.345326	42
.614665	4.65	.959654	.97	.655011	5.62	.344989	41
9.614944	4.65	9.959596	.95	9.655348	5.60	0.344652	40
.615223	4.65	.959539	.95	.655684	5.60	.344316	39
.615502	4.65	.959482	.95	.656020	5.60	.343980	38
.615781	4.65	.959425	.95	.656356	5.60	.343644	37
.616060	4.63	.959368	.97	.656692	5.60	.343308	36
9.616338	4.63	9.959310	.95	9.657028	5.60	0.342972	35
.616616	4.63	.959253	.97	.657364	5.58	.342636	34
.616894	4.63	.959195	.95	.657699	5.58	.342301	33
.617172	4.63	.959138	.97	.658034	5.58	.341966	32
.617450	4.62	.959080	.95	.658369	5.58	.341631	31
9.617727	4.62	9.959023	.97	9.658704	5.58	0.341296	30
.618004	4.62	.958965	.95	.659039	5.57	.340961	29
.618281	4.62	.958908	.97	.659373	5.58	.340627	28
.618558	4.60	.958850	.97	.659708	5.57	.340292	27
.618834	4.60	.958792	.97	.660042	5.57	.339958	26
9.619110	4.60	9.958734	.95	9.660376	5.57	0.339624	25
.619386	4.60	.958677	.97	.660710	5.55	.339290	24
.619662	4.60	.958619	.97	.661043	5.57	.338957	23
.619938	4.58	.958561	.97	.661377	5.55	.338623	22
.620213	4.58	.958503	.97	.661710	5.55	.338290	21
9.620488	4.58	9.958445	.97	9.662043	5.55	0.337957	20
.620763	4.58	.958387	.97	.662376	5.55	.337624	19
.621038	4.58	.958329	.97	.662709	5.55	.337291	18
.621313	4.57	.958271	.97	.663042	5.55	.336958	17
.621587	4.57	.958213	.98	.663375	5.53	.336625	16
9.621861	4.57	9.958154	.97	9.663707	5.53	0.336293	15
.622135	4.57	.958096	.97	.664039	5.53	.335961	14
.622409	4.55	.958038	.98	.664371	5.53	.335629	13
.622682	4.57	.957979	.97	.664703	5.53	.335297	12
.622956	4.55	.957921	.97	.665035	5.52	.334965	11
9.623229	4.55	9.957863	.98	9.665366	5.53	0.334634	10
.623502	4.53	.957804	.97	.665698	5.52	.334302	9
.623774	4.55	.957746	.98	.666029	5.52	.333971	8
.624047	4.53	.957687	.98	.666360	5.52	.333640	7
.624319	4.53	.957628	.97	.666691	5.50	.333309	6
9.624591	4.53	9.957570	.98	9.667021	5.52	0.332979	5
.624863	4.53	.957511	.98	.667352	5.50	.332648	4
.625135	4.52	.957452	.98	.667682	5.52	.332318	3
.625406	4.52	.957393	.97	.668013	5.50	.331987	2
.625677	4.52	.957335	.98	.668343	5.50	.331657	1
9.625948		9.957276		9.668673		0.331327	0
Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.
0	9.625948	4.52	9.957276	.98	9.668673	5.48	0.331327
1	.626219	4.52	.957217	.98	.669002	5.50	.330998
2	.626490	4.50	.957158	.98	.669332	5.48	.330668
3	.626760	4.50	.957099	.98	.669661	5.50	.330339
4	.627030	4.50	.957040	.98	.669991	5.48	.330009
5	9.627300	4.50	9.956981	1.00	9.670320	5.48	0.329680
6	.627570	4.50	.956921	.98	.670649	5.47	.329351
7	.627840	4.48	.956862	.98	.670977	5.48	.329023
8	.628109	4.48	.956803	.98	.671306	5.48	.328694
9	.628378	4.48	.956744	1.00	.671635	5.47	.328365
10	9.628647	4.48	9.956684	.98	9.671963	5.47	0.328037
11	.628916	4.48	.956625	.98	.672291	5.47	.327709
12	.629185	4.47	.956566	1.00	.672619	5.47	.327381
13	.629453	4.47	.956506	.98	.672947	5.45	.327053
14	.629721	4.47	.956447	1.00	.673274	5.47	.326726
15	9.629989	4.47	9.956387	1.00	9.673602	5.45	0.326398
16	.630257	4.45	.956327	.98	.673929	5.47	.326071
17	.630524	4.47	.956268	1.00	.674257	5.45	.325743
18	.630792	4.45	.956208	1.00	.674584	5.45	.325416
19	.631059	4.45	.956148	.98	.674911	5.43	.325089
20	9.631326	4.45	9.956089	1.00	9.675237	5.45	0.324763
21	.631593	4.43	.956029	1.00	.675564	5.43	.324436
22	.631859	4.43	.955969	1.00	.675890	5.45	.324110
23	.632125	4.45	.955909	1.00	.676217	5.43	.323783
24	.632392	4.43	.955849	1.00	.676543	5.43	.323457
25	9.632658	4.42	9.955789	1.00	9.676869	5.42	0.323131
26	.632923	4.43	.955729	1.00	.677194	5.43	.322806
27	.633189	4.42	.955669	1.00	.677520	5.43	.322480
28	.633454	4.42	.955609	1.02	.677846	5.42	.322154
29	.633719	4.42	.955548	1.00	.678171	5.42	.321829
30	9.633984	4.42	9.955488	1.00	9.678496	5.42	0.321504
31	.634249	4.42	.955428	1.00	.678821	5.42	.321179
32	.634514	4.40	.955368	1.02	.679146	5.42	.320854
33	.634778	4.40	.955307	1.00	.679471	5.40	.320529
34	.635042	4.40	.955247	1.02	.679795	5.42	.320205
35	9.635306	4.40	9.955186	1.00	9.680120	5.40	0.319880
36	.635570	4.40	.955126	1.02	.680444	5.40	.319556
37	.635834	4.38	.955065	1.00	.680768	5.40	.319232
38	.636097	4.38	.955005	1.02	.681092	5.40	.318908
39	.636360	4.38	.954944	1.02	.681416	5.40	.318584
40	9.636623	4.38	9.954883	1.00	9.681740	5.38	0.318260
41	.636886	4.37	.954823	1.02	.682063	5.40	.317937
42	.637148	4.38	.954762	1.02	.682387	5.38	.317613
43	.637411	4.37	.954701	1.02	.682710	5.38	.317290
44	.637673	4.37	.954640	1.02	.683033	5.38	.316967
45	9.637935	4.37	9.954579	1.02	9.683356	5.38	0.316644
46	.638197	4.35	.954518	1.02	.683679	5.37	.316321
47	.638458	4.37	.954457	1.02	.684001	5.38	.315999
48	.638720	4.35	.954396	1.02	.684324	5.37	.315676
49	.638981	4.35	.954335	1.02	.684646	5.37	.315354
50	9.639242	4.35	9.954274	1.02	9.684968	5.37	0.315032
51	.639503	4.35	.954213	1.02	.685290	5.37	.314710
52	.639764	4.33	.954152	1.03	.685612	5.37	.314388
53	.640024	4.33	.954090	1.02	.685934	5.35	.314066
54	.640284	4.33	.954029	1.02	.686255	5.37	.313745
55	9.640544	4.33	9.953968	1.03	9.686577	5.35	0.313423
56	.640804	4.33	.953906	1.02	.686898	5.35	.313102
57	.641064	4.33	.953845	1.03	.687219	5.35	.312781
58	.641324	4.32	.953783	1.02	.687540	5.35	.312460
59	.641583	4.32	.953722	1.03	.687861	5.35	.312139
60	9.641842		9.953660		9.688182		0.311818
	Cos.	D. 1″.	Sin.	D. 1″	Cot.	D. 1″.	Tan.

Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
9.641842	4.32	9.953660	1.02	9.688182	5.33	0.311818	60
.642101	4.32	.953599	1.03	.688502	5.35	.311498	59
.642360	4.30	.953537	1.03	.688823	5.33	.311177	58
.642618	4.32	.953475	1.03	.689143	5.33	.310857	57
.642877	4.30	.953413	1.02	.689463	5.33	.310537	56
9.643135	4.30	9.953352	1.03	9.689783	5.33	0.310217	55
.643393	4.28	.953290	1.03	.690103	5.33	.309897	54
.643650	4.30	.953228	1.03	.690423	5.32	.309577	53
.643908	4.28	.953166	1.03	.690742	5.33	.309258	52
.644165	4.30	.953104	1.03	.691062	5.32	.308938	51
9.644423	4.28	9.953042	1.03	9.691381	5.32	0.308619	50
.644680	4.27	.952980	1.03	.691700	5.32	.308300	49
.644936	4.28	.952918	1.05	.692019	5.32	.307981	48
.645193	4.28	.952855	1.03	.692338	5.30	.307662	47
.645450	4.27	.952793	1.03	.692656	5.32	.307344	46
9.645706	4.27	9.952731	1.03	9.692975	5.30	0.307025	45
.645962	4.27	.952669	1.05	.693293	5.32	.306707	44
.646218	4.27	.952606	1.03	.693612	5.30	.306388	43
.646474	4.25	.952544	1.05	.693930	5.30	.306070	42
.646729	4.25	.952481	1.03	.694248	5.30	.305752	41
9.646984	4.27	9.952419	1.05	9.694566	5.28	0.305434	40
.647240	4.23	.952356	1.03	.694883	5.30	.305117	39
.647494	4.25	.952294	1.05	.695201	5.28	.304799	38
.647749	4.25	.952231	1.05	.695518	5.30	.304482	37
.648004	4.23	.952168	1.03	.695836	5.28	.304164	36
9.648258	4.23	9.952106	1.05	9.696153	5.28	0.303847	35
.648512	4.23	.952043	1.05	.696470	5.28	.303530	34
.648766	4.23	.951980	1.05	.696787	5.27	.303213	33
.649020	4.23	.951917	1.05	.697103	5.28	.302897	32
.649274	4.22	.951854	1.05	.697420	5.27	.302580	31
9.649527	4.23	9.951791	1.05	9.697736	5.28	0.302264	30
.649781	4.22	.951728	1.05	.698053	5.27	.301947	29
.650034	4.22	.951665	1.05	.698369	5.27	.301631	28
.650287	4.20	.951602	1.05	.698685	5.27	.301315	27
.650539	4.22	.951539	1.05	.699001	5.25	.300999	26
9.650792	4.20	9.951476	1.07	9.699316	5.27	0.300684	25
.651044	4.22	.951412	1.05	.699632	5.25	.300368	24
.651297	4.20	.951349	1.05	.699947	5.27	.300053	23
.651549	4.18	.951286	1.07	.700263	5.25	.299737	22
.651800	4.20	.951222	1.05	.700578	5.25	.299422	21
9.652052	4.20	9.951159	1.05	9.700893	5.25	0.299107	20
.652304	4.18	.951096	1.07	.701208	5.25	.298792	19
.652555	4.18	.951032	1.07	.701523	5.23	.298477	18
.652806	4.18	.950968	1.05	.701837	5.25	.298163	17
.653057	4.18	.950905	1.07	.702152	5.23	.297848	16
9.653308	4.17	9.950841	1.05	9.702466	5.25	0.297534	15
.653558	4.17	.950778	1.07	.702781	5.23	.297219	14
.653808	4.18	.950714	1.07	.703095	5.23	.296905	13
.654059	4.17	.950650	1.07	.703409	5.22	.296591	12
.654309	4.15	.950586	1.07	.703722	5.23	.296278	11
9.654558	4.17	9.950522	1.07	9.704036	5.23	0.295964	10
.654808	4.17	.950458	1.07	.704350	5.22	.295650	9
.655058	4.15	.950394	1.07	.704663	5.22	.295337	8
.655307	4.15	.950330	1.07	.704976	5.23	.295024	7
.655556	4.15	.950 6	1.07	.705290	5.22	.294710	6
9.655805	4.15	9.950202	1.07	9.705603	5.22	0.294397	5
.656054	4.13	.950138	1.07	.705916	5.20	.294084	4
.656302	4.15	.950074	1.07	.706228	5.22	.293772	3
.656551	4.13	.950010	1.08	.706541	5.22	.293459	2
.656799	4.13	.949945	1.07	.706854	5.20	.293146	1
9.657047		9.949881		9.707166		0.292834	0
Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	

LOGARITHMIC SINES

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.
0	9.657047	4.13	9.949881	1.08	9.707166	5.20	0.2928
1	.657295	4.12	.949816	1.07	.707478	5.20	.2925
2	.657542	4.13	.949752	1.07	.707790	5.20	.2922
3	.657790	4.12	.949688	1.08	.708102	5.20	.2918
4	.658037	4.12	.949623	1.08	.708414	5.20	.2915
5	9.658284	4.12	9.949558	1.07	9.708726	5.18	0.2912
6	.658531	4.12	.949494	1.08	.709037	5.20	.2909
7	.658778	4.12	.949429	1.08	.709349	5.18	.2906
8	.659025	4.10	.949364	1.07	.709660	5.18	.2903
9	.659271	4.10	.949300	1.08	.709971	5.18	.2900
10	9.659517	4.10	9.949235	1.08	9.710282	5.18	0.2897
11	.659763	4.10	.949170	1.08	.710593	5.18	.2894
12	.660009	4.10	.949105	1.08	.710904	5.18	.2890
13	.660255	4.10	.949040	1.08	.711215	5.17	.2887
14	.660501	4.08	.948975	1.08	.711525	5.18	.2884
15	9.660746	4.08	9.948910	1.08	9.711836	5.17	0.2881
16	.660991	4.08	.948845	1.08	.712146	5.17	.2878
17	.661236	4.08	.948780	1.08	.712456	5.17	.2875
18	.661481	4.08	.948715	1.08	.712766	5.17	.2871
19	.661726	4.07	.948650	1.10	.713076	5.17	.2869
20	9.661970	4.07	9.948584	1.08	9.713386	5.17	0.2866
21	.662214	4.08	.948519	1.08	.713696	5.15	.2863
22	.662459	4.07	.948454	1.10	.714005	5.15	.2859
23	.662703	4.05	.948388	1.08	.714314	5.17	.2856
24	.662946	4.07	.948323	1.10	.714624	5.15	.2853
25	9.663190	4.05	9.948257	1.08	9.714933	5.15	0.2850
26	.663433	4.07	.948192	1.10	.715242	5.15	.2847
27	.663677	4.05	.948126	1.10	.715551	5.15	.2844
28	.663920	4.05	.948060	1.08	.715860	5.13	.2841
29	.664163	4.05	.947995	1.10	.716168	5.15	.2838
30	9.664406	4.03	9.947929	1.10	9.716477	5.13	0.2835
31	.664648	4.05	.947863	1.10	.716785	5.13	.2832
32	.664891	4.03	.947797	1.10	.717093	5.13	.2829
33	.665133	4.03	.947731	1.10	.717401	5.13	.2825
34	.665375	4.03	.947665	1.08	.717709	5.13	.2822
35	9.665617	4.03	9.947600	1.12	9.718017	5.13	0.2819
36	.665859	4.02	.947533	1.10	.718325	5.13	.2816
37	.666100	4.03	.947467	1.10	.718633	5.12	.281
38	.666342	4.02	.947401	1.10	.718940	5.13	.2810
39	.666583	4.02	.947335	1.10	.719248	5.12	.2807
40	9.666824	4.02	9.947269	1.10	9.719555	5.12	0.2804
41	.667065	4.00	.947203	1.12	.719862	5.12	.2801
42	.667305	4.02	.947136	1.10	.720169	5.12	.2798
43	.667546	4.00	.947070	1.10	.720476	5.12	.2795
44	.667786	4.02	.947004	1.12	.720783	5.10	.2792
45	9.668027	4.00	9.946937	1.10	9.721089	5.12	0.2789
46	.668267	3.98	.946871	1.12	.721396	5.10	.2786
47	.668506	4.00	.946804	1.10	.721702	5.12	.278
48	.668746	4.00	.946738	1.12	.722009	5.10	.2779
49	.668986	3.98	.946671	1.12	.722315	5.10	.2776
50	9.669225	3.98	9.946604	1.10	9.722621	5.10	0.2773
51	.669464	3.98	.946538	1.12	.722927	5.08	.2770
52	.669703	3.98	.946471	1.12	.723232	5.10	.2767
53	.669942	3.98	.946404	1.12	.723538	5.10	.2764
54	.670181	3.97	.946337	1.12	.723844	5.08	.2761
55	9.670419	3.98	9.946270	1.12	9.724149	5.08	0.2758
56	.670658	3.97	.946203	1.12	.724454	5.10	.2755
57	.670896	3.97	.946136	1.12	.724760	5.08	.275
58	.671134	3.97	.946069	1.12	.725065	5.08	.2749
59	.671372	3.95	.946002	1.12	.725370	5.07	.2746
60	9.671609		9.945935		9.725674		0.27
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	T

	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
9	3.97	9.945935	1.12	9.725674	5.08	0.274326	60
7	3.95	945868	1.13	.725979	5.08	.274021	59
4	3.95	.945800	1.12	.726284	5.07	.273716	58
1	3.95	.945733	1.12	.726588	5.07	.273412	57
8	3.95	.945666	1.13	.726892	5.08	.273108	56
5	3.95	9.945598	1.12	9.727197	5.07	0.272803	55
2	3.93	.945531	1.12	.727501	5.07	.272499	54
8	3.95	.945464	1.13	.727805	5.07	.272195	53
5	3.93	.945396	1.13	.728109	5.05	.271891	52
1	3.93	.945328	1.12	.728412	5.07	.271588	51
7	3.93	9.945261	1.13	9.728716	5.07	0.271284	50
3	3.92	.945193	1.13	.729020	5.05	.270980	49
8	3.93	.945125	1.12	.729323	5.05	.270677	48
4	3.92	.945058	1.13	.729626	5.05	.270374	47
9	3.93	.944990	1.13	.729929	5.07	.270071	46
5	3.92	9.944922	1.13	9.730233	5.03	0.269767	45
0	3.90	.944854	1.13	.730535	5.05	.269465	44
4	3.92	.944786	1.13	.730838	5.05	.269162	43
9	3.92	.944718	1.13	.731141	5.05	.268859	42
4	3.90	.944650	1.13	.731444	5.03	.268556	41
6	3.90	9.944582	1.13	9.731746	5.03	0.268254	40
2	3.90	.944514	1.13	.732048	5.05	.267952	39
6	3.90	.944446	1.15	.732351	5.03	.267649	38
0	3.90	.944377	1.13	.732653	5.03	.267347	37
4	3.90	.944309	1.13	.732955	5.03	.267045	36
8	3.88	9.944241	1.15	9.733257	5.02	0.266743	35
1	3.88	.944172	1.13	.733558	5.03	.266442	34
4	3.88	.944104	1.13	.733860	5.03	.266140	33
7	3.88	.944036	1.15	.734162	5.02	.265838	32
0	3.88	.943967	1.13	.734463	5.02	.265537	31
3	3.87	9.943899	1.15	9.734764	5.03	0.265236	30
5	3.88	.943830	1.15	.735066	5.02	.264934	29
8	3.87	.943761	1.13	.735367	5.02	.264633	28
0	3.87	.943693	1.15	.735668	5.02	.264332	27
2	3.87	.943624	1.15	.735969	5.00	.264031	26
4	3.87	9.943555	1.15	9.736269	5.02	0.263731	25
6	3.87	.943486	1.15	.736570	5.00	.263430	24
8	3.85	.943417	1.15	.736870	5.02	.263130	23
9	3.85	.943348	1.15	.737171	5.00	.262829	22
0	3.87	.943279	1.15	.737471	5.00	.262529	21
2	3.85	9.943210	1.15	9.737771	5.00	0.262229	20
3	3.83	.943141	1.15	.738071	5.00	.261929	19
3	3.85	.943072	1.15	.738371	5.00	.261629	18
4	3.85	.943003	1.15	.738671	5.00	.261329	17
5	3.83	.942934	1.17	.738971	5.00	.261029	16
5	3.83	9.942864	1.15	9.739271	4.98	0.260729	15
5	3.83	.942795	1.15	.739570	5.00	.260430	14
5	3.83	.942726	1.17	.739870	4.98	.260130	13
5	3.83	.942656	1.15	.740169	4.98	.259831	12
5	3.82	.942587	1.17	.740468	4.98	.259532	11
4	3.83	9.942517	1.15	9.740767	4.98	0.259233	10
4	3.82	.942448	1.17	.741066	4.98	.258934	9
3	3.82	.942378	1.17	.741365	4.98	.258635	8
2	3.82	.942308	1.15	741664	4.97	.258336	7
1	3.82	942239	1.17	.741962	4.98	258038	6
0	3.80	9.942169	1.17	9.742261	4.97	0.257739	5
8	3.82	.942099	1.17	.742559	4.95	.257441	4
7	3.80	.942029	1.17	.742858	4.97	.257142	3
5	3.80	.941959	1.17	.743156	4.97	.256844	2
3	3.80	.941889	1.17	.743454	4.97	.256546	1
1		9.941819		9.743752		0.256248	0
	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.
0	9.685571	3.80	9.941819	1.17	9.743752	4.97	0.256
1	.685799	3.80	.941749	1.17	.744050	4.97	.255
2	.686027	3.78	.941679	1.17	.744348	4.95	.255
3	.686254	3.80	.941609	1.17	.744645	4.97	.255
4	.686482	3.78	.941539	1.17	.744943	4.95	.255
5	9.686709	3.78	9.941469	1.18	9.745240	4.97	0.254
6	.686936	3.78	.941398	1.17	.745538	4.95	.254
7	.687163	3.77	.941328	1.17	.745835	4.95	.254
8	.687389	3.78	.941258	1.18	.746132	4.95	.253
9	.687616	3.78	.941187	1.17	.746429	4.95	.253
10	9.687843	3.77	9.941117	1.18	9.746726	4.95	0.253
11	.688069	3.77	.941046	1.18	.747023	4.93	.252
12	.688295	3.77	.940975	1.17	.747319	4.95	.252
13	.688521	3.77	.940905	1.18	.747616	4.95	.252
14	.688747	3.75	.940834	1.18	.747913	4.93	.252
15	9.688972	3.77	9.940763	1.17	9.748209	4.93	0.251
16	.689198	3.75	.940693	1.18	.748505	4.93	.25
17	.689423	3.75	.940622	1.18	.748801	4.93	.25
18	.689648	3.75	.940551	1.18	.749097	4.93	.25
19	.689873	3.75	.940480	1.18	.749393	4.93	.25
20	9.690098	3.75	9.940409	1.18	9.749689	4.93	0.25
21	.690323	3.75	.940338	1.18	.749985	4.93	.25
22	.690548	3.73	.940267	1.18	.750281	4.92	.24
23	.690772	3.73	.940196	1.18	.750576	4.93	.24
24	.690996	3.73	.940125	1.18	.750872	4.92	.24
25	9.691220	3.73	9.940054	1.20	9.751167	4.92	0.24
26	.691444	3.73	.939982	1.18	.751462	4.92	.24
27	.691668	3.73	.939911	1.18	.751757	4.92	.24
28	.691892	3.72	.939840	1.20	.752052	4.92	.24
29	.692115	3.73	.939768	1.18	.752347	4.92	.24
30	9.692339	3.72	9.939697	1.20	9.752642	4.92	0.24
31	.692562	3.72	.939625	1.18	.752937	4.90	.24
32	.692785	3.72	.939554	1.20	.753231	4.92	.24
33	.693008	3.72	.939482	1.20	.753526	4.90	.24
34	.693231	3.70	.939410	1.18	.753820	4.92	.24
35	9.693453	3.72	9.939339	1.20	9.754115	4.90	0.24
36	.693676	3.70	.939267	1.20	.754409	4.90	.24
37	.693898	3.70	.939195	1.20	.754703	4.90	.24
38	.694120	3.70	.939123	1.18	.754997	4.90	.24
39	.694342	3.70	.939052	1.20	.755291	4.90	.24
40	9.694564	3.70	9.938980	1.20	9.755585	4.88	0.24
41	.694786	3.68	.938908	1.20	.755878	4.90	.24
42	.695007	3.70	.938836	1.22	.756172	4.88	.24
43	.695229	3.68	.938763	1.20	.756465	4.90	.24
44	.695450	3.68	.938691	1.20	.756759	4.88	.24
45	9.695671	3.68	9.938619	1.20	9.757052	4.88	0.24
46	.695892	3.68	.938547	1.20	.757345	4.88	.24
47	.696113	3.68	.938475	1.22	.757638	4.88	.24
48	.696334	3.67	.938402	1.20	.757931	4.88	.24
49	.696554	3.68	.938330	1.20	.758224	4.88	.24
50	9.696775	3.67	9.938258	1.22	9.758517	4.88	0.24
51	.696995	3.67	.938185	1.20	.758810	4.87	.24
52	.697215	3.67	.938113	1.22	.759102	4.88	.24
53	.697435	3.65	.938040	1.22	.759395	4.87	.24
54	.697654	3.67	.937967	1.20	.759687	4.87	.24
55	9.697874	3.67	9.937895	1.22	9.759979	4.88	0.24
56	.698094	3.65	.937822	1.22	.760272	4.87	.23
57	.698313	3.65	.937749	1.22	.760564	4.87	.23
58	.698532	3.65	.937676	1.20	.760856	4.87	.23
59	.698751	3.65	.937604	1.22	.761148	4.85	.23
60	9.698970		9.937531		9.761439		0.23
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	T

Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
9.698970	3.65	9.937531	1.22	9.761439	4.87	0.238561	60
.699189	3.63	.937458	1.22	.761731	4.87	.238269	59
.699407	3.65	.937385	1.22	.762023	4.85	.237977	58
.699626	3.63	.937312	1.23	.762314	4.87	.237686	57
.699844	3.63	.937238	1.22	.762606	4.85	.237394	56
9.700062	3.63	9.937165	1.22	9.762897	4.85	0.237103	55
.700280	3.63	.937092	1.22	.763188	4.85	.236812	54
.700498	3.63	.937019	1.22	.763479	4.85	.236521	53
.700716	3.62	.936946	1.23	.763770	4.85	.236230	52
.700933	3.63	.936872	1.22	.764061	4.85	.235939	51
9.701151	3.62	9.936799	1.23	9.764352	4.85	0.235648	50
.701368	3.62	.936725	1.22	.764643	4.83	.235357	49
.701585	3.62	.936652	1.23	.764933	4.85	.235067	48
.701802	3.62	.936578	1.22	.765224	4.83	.234776	47
.702019	3.62	.936505	1.23	.765514	4.85	.234486	46
9.702236	3.60	9.936431	1.23	9.765805	4.83	0.234195	45
.702452	3.62	.936357	1.22	.766095	4.83	.233905	44
.702669	3.60	.936284	1.23	.766385	4.83	.233615	43
.702885	3.60	.936210	1.23	.766675	4.83	.233325	42
.703101	3.60	.936136	1.23	.766965	4.83	.233035	41
9.703317	3.60	9.936062	1.23	9.767255	4.83	0.232745	40
.703533	3.60	.935988	1.23	.767545	4.82	.232455	39
.703749	3.58	.935914	1.23	.767834	4.83	.232166	38
.703964	3.58	.935840	1.23	.768124	4.83	.231876	37
.704179	3.60	.935766	1.23	.768414	4.82	.231586	36
9.704395	3.58	9.935692	1.23	9.768703	4.82	0.231297	35
.704610	3.58	.935618	1.25	.768992	4.82	.231008	34
.704825	3.58	.935543	1.23	.769281	4.83	.230719	33
.705040	3.57	.935469	1.23	.769571	4.82	.230429	32
.705254	3.58	.935395	1.25	.769860	4.80	.230140	31
9.705469	3.57	9.935320	1.23	9.770148	4.82	0.229852	30
.705683	3.58	.935246	1.25	.770437	4.82	.229563	29
.705898	3.57	.935171	1.23	.770726	4.82	.229274	28
.706112	3.57	.935097	1.25	.771015	4.80	.228985	27
.706326	3.55	.935022	1.23	.771303	4.82	.228697	26
9.706539	3.57	9.934948	1.25	9.771592	4.80	0.228408	25
.706753	3.57	.934873	1.25	.771880	4.80	.228120	24
.706967	3.55	.934798	1.25	.772168	4.82	.227832	23
.707180	3.55	.934723	1.23	.772457	4.80	.227543	22
.707393	3.55	.934649	1.25	.772745	4.80	.227255	21
9.707606	3.55	9.934574	1.25	9.773033	4.80	0.226967	20
.707819	3.55	.934499	1.25	.773321	4.78	.226679	19
.708032	3.55	.934424	1.25	.773608	4.80	.226392	18
.708245	3.55	.934349	1.25	.773896	4.80	.226104	17
.708458	3.53	.934274	1.25	.774184	4.78	.225816	16
9.708670	3.53	9.934199	1.27	9.774471	4.80	0.225529	15
.708882	3.53	.934123	1.25	.774759	4.78	.225241	14
.709094	3.53	.934048	1.25	.775046	4.78	.224954	13
.709306	3.53	.933973	1.25	.775333	4.80	.224667	12
.709518	3.53	.933898	1.27	.775621	4.78	.224379	11
9.709730	3.52	9.933822	1.25	9.775908	4.78	0.224092	10
.709941	3.53	.933747	1.27	.776195	4.78	.223805	9
.710153	3.52	.933671	1.25	.776482	4.77	.223518	8
.710364	3.52	.933596	1.27	.776768	4.78	.223232	7
.710575	3.52	933520	1.25	.777055	4.78	.222945	6
9.710786	3.52	9.933445	1.27	9.777342	4.77	0.222658	5
.710997	3.52	.933369	1.27	.777628	4.78	.222372	4
.711208	3.52	.933293	1.27	.777915	4.77	.222085	3
.711419	3.50	.933217	1.27	.778201	4.78	.221799	2
.711629	3.50	.933141	1.25	.778488	4.77	.221512	1
9.711839		9.933066		9.778774		0.221226	0
Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

LOGARITHMIC SINES

D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
724210	3.37	9.928420	1.30	9.795789	4.68	0.204211	60
724412	3.37	.928342	1.32	.796070	4.68	.203930	59
724614	3.37	.928263	1.33	.796351	4.68	.203649	58
724816	3.35	.928183	1.32	.796632	4.68	.203368	57
725017	3.37	.928104	1.32	.796913	4.68	.203087	56
725219	3.35	9.928025	1.32	9.797194	4.67	0.202806	55
725420	3.37	.927946	1.32	.797474	4.68	.202526	54
725622	3.35	.927867	1.33	.797755	4.68	.202245	53
725823	3.35	.927787	1.32	.798036	4.67	.201964	52
726024	3.35	.927708	1.32	.798316	4.67	.201684	51
726225	3.35	9.927629	1.33	9.798596	4.68	0.201404	50
726426	3.33	.927549	1.32	.798877	4.67	.201123	49
726626	3.35	.927470	1.33	.799157	4.67	.200843	48
726827	3.33	.927390	1.33	.799437	4.67	.200563	47
727027	3.35	.927310	1.32	.799717	4.67	.200283	46
727228	3.33	9.927231	1.33	9.799997	4.67	0.200003	45
727428	3.33	.927151	1.33	.800277	4.67	.199723	44
727628	3.33	.927071	1.33	.800557	4.65	.199443	43
727828	3.32	.926991	1.33	.800836	4.67	.199164	42
728027	3.33	.926911	1.33	.801116	4.67	.198884	41
728227	3.33	9.926831	1.33	9.801396	4.65	0.198604	40
728427	3.32	.926751	1.33	.801675	4.67	.198325	39
728626	3.32	.926671	1.33	.801955	4.65	.198045	38
728825	3.32	.926591	1.33	.802234	4.65	.197766	37
729024	3.32	.926511	1.33	.802513	4.65	.197487	36
29223	3.32	9.926431	1.33	9.802792	4.67	0.197208	35
29422	3.32	.926351	1.35	.803072	4.65	.196928	34
29621	3.32	.926270	1.33	.803351	4.65	.196649	33
9820	3.30	.926190	1.33	.803630	4.65	.196370	32
0018	3.32	.926110	1.35	.803909	4.63	.196091	31
0217	3.30	9.926029	1.33	9.804187	4.65	0.195813	30
0415	3.30	.925949	1.35	.804466	4.65	.195534	29
0613	3.30	.925868	1.33	.804745	4.63	.195255	28
0811	3.30	.925788	1.35	.805023	4.65	.194977	27
009	3.28	.925707	1.35	.805302	4.63	.194698	26
206	3.30	9.925626	1.35	9.805580	4.65	0.194420	25
404	3.30	.925545	1.33	.805859	4.63	.194141	24
02	3.28	.925465	1.35	.806137	4.63	.193863	23
99	3.28	.925384	1.35	.806415	4.63	.193585	22
96	3.28	.925303	1.35	.806693	4.63	.193307	21
93	3.28	9.925222	1.35	9.806971	4.63	0.193029	20
90	3.28	.925141	1.35	.807249	4.63	.192751	19
87	3.28	.925060	1.35	.807527	4.63	.192473	18
4	3.27	.924979	1.37	.807805	4.63	.192195	17
0	3.28	.924897	1.35	.808083	4.63	.191917	[redacted]
7	3.27	9.924816	1.35	9.808361	4.62	0.191639	15
3	3.27	.924735	1.35	.808638	4.63	.191362	14
)	3.27	.924654	1.37	.808916	4.62	.191084	13
i	3.27	.924572	1.35	.809193	4.63	.190807	12
	3.27	.924491	1.37	.809471	4.62	.190529	11
	3.27	9.924409	1.35	9.809748	4.62	0.190252	10
	3.27	.924328	1.37	.810025	4.62	.189975	9
	3.25	.924246	1.37	.810302	4.63	.189698	8
	3.25	.924164	1.35	.810580	4.62	.189420	7
	3.27	.924083	1.37	.810857	4.62	.189143	6
	3.25	9.924001	1.37	9.811134	4.60	0.188866	5
	3.25	.923919	1.37	.811410	4.62	.188590	4
	3.23	.923837	1.37	.811687	4.62	.188313	3
	3.25	.923755	1.37	.811964	4.62	.188036	2
	3.25	.923673	1.37	.812241	4.60	.187759	1
		9.923591		9.812517		0.187483	0
	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.
0	9.736109	3.23	9.923591	1.37	9.812517	4.62	0.187483
1	.736303	3.25	.923509	1.37	.812794	4.60	.187206
2	.736498	3.23	.923427	1.37	.813070	4.62	.186930
3	.736692	3.23	.923345	1.37	.813347	4.60	.186653
4	.736886	3.23	.923263	1.37	.813623	4.60	.186377
5	9.737080	3.23	9.923181	1.38	9.813899	4.62	0.186101
6	.737274	3.22	.923098	1.37	.814176	4.60	.185824
7	.737467	3.23	.923016	1.38	.814452	4.60	.185548
8	.737661	3.23	.922933	1.37	.814728	4.60	.185272
9	.737855	3.22	.922851	1.38	.815004	4.60	.184996
10	9.738048	3.22	9.922768	1.37	9.815280	4.58	0.184720
11	.738241	3.22	.922686	1.38	.815555	4.60	.184445
12	.738434	3.22	.922603	1.38	.815831	4.60	.184169
13	.738627	3.22	.922520	1.37	.816107	4.58	.183893
14	.738820	3.22	.922438	1.38	.816382	4.60	.183618
15	9.739013	3.22	9.922355	1.38	9.816658	4.58	0.183342
16	.739206	3.20	.922272	1.38	.816933	4.60	.183067
17	.739398	3.20	.922189	1.38	.817209	4.58	.182791
18	.739590	3.22	.922106	1.38	.817484	4.58	.182516
19	.739783	3.20	.922023	1.38	.817759	4.60	.182241
20	9.739975	3.20	9.921940	1.38	9.818035	4.58	0.181965
21	.740167	3.20	.921857	1.38	.818310	4.58	.181690
22	.740359	3.18	.921774	1.38	.818585	4.58	.181415
23	.740550	3.20	.921691	1.40	.818860	4.58	.181140
24	.740742	3.20	.921607	1.38	.819135	4.58	.180865
25	9.740934	3.18	9.921524	1.38	9.819410	4.57	0.180590
26	.741125	3.18	.921441	1.40	.819684	4.58	.180316
27	.741316	3.20	.921357	1.38	.819959	4.58	.180041
28	.741508	3.18	.921274	1.40	.820234	4.57	.179766
29	.741699	3.17	.921190	1.38	.820508	4.58	.179492
30	9.741889	3.18	9.921107	1.40	9.820783	4.57	0.179217
31	.742080	3.18	.921023	1.40	.821057	4.58	.178943
32	.742271	3.18	.920939	1.38	.821332	4.57	.178668
33	.742462	3.17	.920856	1.40	.821606	4.57	.178394
34	.742652	3.17	.920772	1.40	.821880	4.57	.178120
35	9.742842	3.18	9.920688	1.40	9.822154	4.58	0.177846
36	.743033	3.17	.920604	1.40	.822429	4.57	.177571
37	.743223	3.17	.920520	1.40	.822703	4.57	.177297
38	.743413	3.15	.920436	1.40	.822977	4.57	.177023
39	.743602	3.17	.920352	1.40	.823251	4.55	.176749
40	9.743792	3.17	9.920268	1.40	9.823524	4.57	0.176476
41	.743982	3.15	.920184	1.42	.823798	4.57	.176202
42	.744171	3.17	.920099	1.40	.824072	4.55	.175928
43	.744361	3.15	.920015	1.40	.824345	4.57	.175655
44	.744550	3.15	.919931	1.42	.824619	4.57	.175381
45	9.744739	3.15	9.919846	1.40	9.824893	4.55	0.175107
46	.744928	3.15	.919762	1.42	.825166	4.55	.174834
47	.745117	3.15	.919677	1.40	.825439	4.57	.174561
48	.745306	3.13	.919593	1.42	.825713	4.55	.174287
49	.745494	3.15	.919508	1.40	.825986	4.55	.174014
50	9.745683	3.13	9.919424	1.42	9.826259	4.55	0.173741
51	.745871	3.15	.919339	1.42	.826532	4.55	.173468
52	.746060	3.13	.919254	1.42	.826805	4.55	.173195
53	.746248	3.13	.919169	1.40	.827078	4.55	.172922
54	.746436	3.13	.919085	1.42	.827351	4.55	.172649
55	9.746624	3.13	9.919000	1.42	9.827624	4.55	0.172376
56	.746812	3.12	.918915	1.42	.827897	4.55	.172103
57	.746999	3.13	.918830	1.42	.828170	4.53	.171830
58	.747187	3.12	.918745	1.43	.828442	4.55	.171558
59	.747374	3.13	.918659	1.42	.828715	4.53	.171285
60	9.747562		9.918574		9.828987		0.171013
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.

D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
3.12	9.918574	1.42	9.828987	4.55	0.171013	60
3.12	.918489	1.42	.829260	4.53	.170740	59
3.12	.918404	1.43	.829532	4.55	.170468	58
3.12	.918318	1.42	.829805	4.53	.170195	57
3.12	.918233	1.43	.830077	4.53	.169923	56
3.10	9.918147	1.42	9.830349	4.53	0.169651	55
3.12	.918062	1.43	.830621	4.53	.169379	54
3.10	.917976	1.42	.830893	4.53	.169107	53
3.12	.917891	1.43	.831165	4.53	.168835	52
3.10	.917805	1.43	.831437	4.53	.168563	51
3.10	9.917719	1.42	9.831709	4.53	0.168291	50
3.10	.917634	1.43	.831981	4.53	.168019	49
3.10	.917548	1.43	.832253	4.53	.167747	48
3.08	.917462	1.43	.832525	4.52	.167475	47
3.10	.917376	1.43	.832796	4.53	.167204	46
3.08	9.917290	1.43	9.833068	4.52	0.166932	45
3.10	.917204	1.43	.833339	4.53	.166661	44
3.08	.917118	1.43	.833611	4.52	.166389	43
3.08	.917032	1.43	.833882	4.53	.166118	42
3.08	.916946	1.45	.834154	4.52	.165846	41
3.08	9.916859	1.43	9.834425	4.52	0.165575	40
3.08	.916773	1.43	.834696	4.52	.165304	39
3.08	.916687	1.45	.834967	4.52	.165033	38
3.07	.916600	1.43	.835238	4.52	.164762	37
3.08	.916514	1.45	.835509	4.52	.164491	36
3.07	9.916427	1.43	9.835780	4.52	0.164220	35
3.07	.916341	1.45	.836051	4.52	.163949	34
3.07	.916254	1.45	.836322	4.52	.163678	33
3.07	.916167	1.43	.836593	4.52	.163407	32
3.07	.916081	1.45	.836864	4.50	.163136	31
3.07	9.915994	1.45	9.837134	4.52	0.162866	30
3.05	.915907	1.45	.837405	4.50	.162595	29
3.07	.915820	1.45	.837675	4.52	.162325	28
3.05	.915733	1.45	.837946	4.50	.162054	27
3.07	.915646	1.45	.838216	4.52	.161784	26
3.05	9.915559	1.45	9.838487	4.50	0.161513	25
3.05	.915472	1.45	.838757	4.50	.161243	24
3.05	.915385	1.47	.839027	4.50	.160973	23
3.05	.915297	1.45	.839297	4.52	.160703	22
3.03	.915210	1.45	.839568	4.50	.160432	21
3.05	9.915123	1.47	9.839838	4.50	0.160162	20
3.05	.915035	1.45	.840108	4.50	.159892	19
3.03	.914948	1.47	.840378	4.50	.159622	18
3.03	.914860	1.45	.840648	4.48	.159352	17
3.03	.914773	1.47	.840917	4.50	.159083	16
3.03	9.914685	1.45	9.841187	4.50	0.158813	15
3.03	.914598	1.47	.841457	4.50	.158543	14
3.03	.914510	1.47	.841727	4.48	.158273	13
3.03	.914422	1.47	.841996	4.50	.158004	12
3.03	.914334	1.47	.842266	4.48	.157734	11
3.02	9.914246	1.47	9.842535	4.50	0.157465	10
3.02	.914158	1.47	.842805	4.48	.157195	9
3.03	.914070	1.47	.843074	4.48	.156926	8
3.02	.913982	1.47	.843343	4.48	.156657	7
3.02	.913894	1.47	.843612	4.50	.156388	6
3.02	9.913806	1.47	9.843882	4.48	0.156118	5
3.02	.913718	1.47	.844151	4.48	.155849	4
3.00	.913630	1.48	.844420	4.48	.155580	3
3.02	.913541	1.47	.844689	4.48	.155311	2
3.00	.913453	1.47	.844958	4.48	.155042	1
	9.913365		9.845227		0.154773	0
D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.758591	3.02	9.913365	1.48	9.845227	4.48	0.154773	60
1	.758772	3.00	.913276	1.48	.845496	4.47	.154504	59
2	.758952	3.00	.913187	1.47	.845764	4.48	.154236	58
3	.759132	3.00	.913099	1.48	.846033	4.48	.153967	57
4	.759312	3.00	.913010	1.47	.846302	4.47	.153698	56
5	9.759492	3.00	9.912922	1.48	9.846570	4.48	0.153430	55
6	.759672	3.00	.912833	1.48	.846839	4.48	.153161	54
7	.759852	2.98	.912744	1.48	.847108	4.47	.152892	53
8	.760031	3.00	.912655	1.48	.847376	4.47	.152624	52
9	.760211	2.98	.912566	1.48	.847644	4.48	.152356	51
10	9.760390	2.98	9.912477	1.48	9.847913	4.47	0.152087	50
11	.760569	2.98	.912388	1.48	.848181	4.47	.151819	49
12	.760748	2.98	.912299	1.48	.848449	4.47	.151551	48
13	.760927	2.98	.912210	1.48	.848717	4.48	.151283	47
14	.761106	2.98	.912121	1.50	.848986	4.47	.151014	46
15	9.761285	2.98	9.912031	1.48	9.849254	4.47	0.150746	45
16	.761464	2.97	.911942	1.48	.849522	4.47	.150478	44
17	.761642	2.98	.911853	1.50	.849790	4.45	.150210	43
18	.761821	2.97	.911763	1.48	.850057	4.47	.149943	42
19	.761999	2.97	.911674	1.50	.850325	4.47	.149675	41
20	9.762177	2.98	9.911584	1.48	9.850593	4.47	0.149407	40
21	.762356	2.97	.911495	1.50	.850861	4.47	.149139	39
22	.762534	2.97	.911405	1.50	.851129	4.45	.148871	38
23	.762712	2.95	.911315	1.48	.851396	4.47	.148604	37
24	.762889	2.97	.911226	1.50	.851664	4.45	.148336	36
25	9.763067	2.97	9.911136	1.50	9.851931	4.47	0.148069	35
26	.763245	2.95	.911046	1.50	.852199	4.45	.147801	34
27	.763422	2.97	.910956	1.50	.852466	4.45	.147534	33
28	.763600	2.95	.910866	1.50	.852733	4.47	.147267	32
29	.763777	2.95	.910776	1.50	.853001	4.45	.146999	31
30	9.763954	2.95	9.910686	1.50	9.853268	4.45	0.146732	30
31	.764131	2.95	.910596	1.50	.853535	4.45	.146465	29
32	.764308	2.95	.910506	1.52	.853802	4.45	.146198	28
33	.764485	2.95	.910415	1.50	.854069	4.45	.145931	27
34	.764662	2.93	.910325	1.50	.854336	4.45	.145664	26
35	9.764838	2.95	9.910235	1.52	9.854603	4.45	0.145397	25
36	.765015	2.93	.910144	1.50	.854870	4.45	.145130	24
37	.765191	2.93	.910054	1.52	.855137	4.45	.144863	23
38	.765367	2.95	.909963	1.50	.855404	4.45	.144596	22
39	.765544	2.93	.909873	1.52	.855671	4.45	.144329	21
40	9.765720	2.93	9.909782	1.52	9.855938	4.43	0.144062	20
41	.765896	2.93	.909691	1.50	.856204	4.45	.143796	19
42	.766072	2.92	.909601	1.52	.856471	4.43	.143529	18
43	.766247	2.93	.909510	1.52	.856737	4.45	.143263	17
44	.766423	2.92	.909419	1.52	.857004	4.43	.142996	16
45	9.766598	2.93	9.909328	1.52	9.857270	4.45	0.142730	15
46	.766774	2.92	.909237	1.52	.857537	4.43	.142463	14
47	.766949	2.92	.909146	1.52	.857803	4.43	.142197	13
48	.767124	2.93	.909055	1.52	.858069	4.45	.141931	12
49	.767300	2.92	.908964	1.52	.858336	4.43	.141664	11
50	9.767475	2.90	9.908873	1.53	9.858602	4.43	0.141398	10
51	.767649	2.92	.908781	1.52	.858868	4.43	.141132	9
52	.767824	2.92	.908690	1.52	.859134	4.43	.140866	8
53	.767999	2.90	.908599	1.53	.859400	4.43	.140600	7
54	.768173	2.92	.908507	1.52	.859666	4.43	.140334	6
55	9.768348	2.90	9.908416	1.53	9.859932	4.43	0.140068	5
56	.768522	2.92	.908324	1.52	.860198	4.43	.139802	4
57	.768697	2.90	.908233	1.53	.860464	4.43	.139536	3
58	.768871	2.90	.908141	1.53	.860730	4.42	.139270	2
59	.769045	2.90	.908049	1.52	.860995	4.43	.139005	1
60	9.769219		9.907958		9.861261		0.138739	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

M.	Sin.	D. 1″.	Cos.	D. 1″.	Tan.	D. 1″.	Cot.	
0	9.769219	2.90	9.907958	1.53	9.861261	4.43	0.138739	60
1	.769393	2.88	.907866	1.53	.861527	4.42	.138473	59
2	.769566	2.90	.907774	1.53	.861792	4.43	.138208	58
3	.769740	2.88	.907682	1.53	.862058	4.42	.137942	57
4	.769913	2.90	.907590	1.53	.862323	4.43	.137677	56
5	9.770087	2.88	9.907498	1.53	9.862589	4.42	0.137411	55
6	.770260	2.88	.907406	1.53	.862854	4.42	.137146	54
7	.770433	2.88	.907314	1.53	.863119	4.43	.136881	53
8	.770606	2.88	.907222	1.55	.863385	4.42	.136615	52
9	.770779	2.88	.907129	1.53	.863650	4.42	.136350	51
10	9.770952	2.88	9.907037	1.53	9.863915	4.42	0.136085	50
11	.771125	2.88	.906945	1.55	.864180	4.42	.135820	49
12	.771298	2.87	.906852	1.53	.864445	4.42	.135555	48
13	.771470	2.88	.906760	1.55	.864710	4.42	.135290	47
14	.771643	2.87	.906667	1.53	.864975	4.42	.135025	46
15	9.771815	2.87	9.906575	1.55	9.865240	4.42	0.134760	45
16	.771987	2.87	.906482	1.55	.865505	4.42	.134495	44
17	.772159	2.87	.906389	1.55	.865770	4.42	.134230	43
18	.772331	2.87	.906296	1.53	.866035	4.42	.133965	42
19	.772503	2.87	.906204	1.55	.866300	4.40	.133700	41
20	9.772675	2.87	9.906111	1.55	9.866564	4.42	0.133436	40
21	.772847	2.85	.906018	1.55	.866829	4.42	.133171	39
22	.773018	2.87	.905925	1.55	.867094	4.40	.132906	38
23	.773190	2.85	.905832	1.55	.867358	4.42	.132642	37
24	.773361	2.87	.905739	1.57	.867623	4.40	.132377	36
25	9.773533	2.85	9.905645	1.55	9.867887	4.42	0.132113	35
26	.773704	2.85	.905552	1.55	.868152	4.40	.131848	34
27	.773875	2.85	.905459	1.55	.868416	4.40	.131584	33
28	.774046	2.85	.905366	1.57	.868680	4.42	.131320	32
29	.774217	2.85	.905272	1.55	.868945	4.40	.131055	31
30	9.774388	2.83	9.905179	1.57	9.869209	4.40	0.130791	30
31	.774558	2.85	.905085	1.55	.869473	4.40	.130527	29
32	.774729	2.83	.904992	1.57	.869737	4.40	.130263	28
33	.774899	2.85	.904898	1.57	.870001	4.40	.129999	27
34	.775070	2.83	.904804	1.55	.870265	4.40	.129735	26
35	9.775240	2.83	9.904711	1.57	9.870529	4.40	0.129471	25
36	.775410	2.83	.904617	1.57	.870793	4.40	.129207	24
37	.775580	2.83	.904523	1.57	.871057	4.40	.128943	23
38	.775750	2.83	.904429	1.57	.871321	4.40	.128679	22
39	.775920	2.83	.904335	1.57	.871585	4.40	.128415	21
40	9.776090	2.82	9.904241	1.57	9.871849	4.38	0.128151	20
41	.776259	2.83	.904147	1.57	.872112	4.40	.127888	19
42	.776429	2.82	.904053	1.57	.872376	4.40	.127624	18
43	.776598	2.83	.903959	1.58	.872640	4.38	.127360	17
44	.776768	2.82	.903864	1.57	.872903	4.40	.127097	16
45	9.776937	2.82	9.903770	1.57	9.873167	4.38	0.126833	15
46	.777106	2.82	.903676	1.58	.873430	4.40	.126570	14
47	.777275	2.82	.903581	1.57	.873694	4.38	.126306	13
48	.777444	2.82	.903487	1.58	.873957	4.38	.126043	12
49	.777613	2.80	.903392	1.57	.874220	4.40	.125780	11
50	9.777781	2.82	9.903298	1.58	9.874484	4.38	0.125516	10
51	.777950	2.82	.903203	1.58	.874747	4.38	.125253	9
52	.778119	2.80	.903108	1.57	.875010	4.38	.124990	8
53	.778287	2.80	.903014	1.58	.875273	4.40	.124727	7
54	.778455	2.82	.902919	1.58	.875537	4.38	.124463	6
55	9.778624	2.80	9.902824	1.58	9.875800	4.38	0.124200	5
56	.778792	2.80	.902729	1.58	.876063	4.38	.123937	4
57	.778960	2.80	.902634	1.58	.876326	4.38	.123674	3
58	.779128	2.78	.902539	1.58	.876589	4.38	.123411	2
59	.779295	2.80	.902444	1.58	.876852	4.37	.123148	1
60	9.779463		9.902349		9.877114		0.122886	
	Cos.	D. 1″.	Sin.	D. 1″.	Cot.	D. 1″.	Tan.	

LOGARITHMIC SINES

M	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.
0	9.779463	2.80	9.902349	1.60	9.877114	4.38	0.122886
1	.779631	2.78	.902253	1.58	.877377	4.38	.122623
2	.779798	2.80	.902158	1.58	.877640	4.38	.122360
3	.779966	2.78	.902063	1.60	.877903	4.37	.122097
4	.780133	2.78	.901967	1.58	.878165	4.38	.121835
5	9.780300	2.78	9.901872	1.60	9.878428	4.38	0.121572
6	.780467	2.78	.901776	1.58	.878691	4.37	.121309
7	.780634	2.78	.901681	1.60	.878953	4.38	.121047
8	.780801	2.78	.901585	1.58	.879216	4.37	.120784
9	.780968	2.77	.901490	1.60	.879478	4.38	.120522
10	9.781134	2.78	9.901394	1.60	9.879741	4.37	0.120259
11	.781301	2.78	.901298	1.60	.880003	4.37	.119997
12	.781468	2.77	.901202	1.60	.880265	4.38	.119735
13	.781634	2.77	.901106	1.60	.880528	4.37	.119472
14	.781800	2.77	.901010	1.60	.880790	4.37	.119210
15	9.781966	2.77	9.900914	1.60	9.881052	4.37	0.118948
16	.782132	2.77	.900818	1.60	.881314	4.38	.118686
17	.782298	2.77	.900722	1.60	.881577	4.37	.118423
18	.782464	2.77	.900626	1.62	.881839	4.37	.118161
19	.782630	2.77	.900529	1.60	.882101	4.37	.117899
20	9.782796	2.75	9.900433	1.60	9.882363	4.37	0.117637
21	.782961	2.77	.900337	1.62	.882625	4.37	.117375
22	.783127	2.75	.900240	1.60	.882887	4.35	.117113
23	.783292	2.77	.900144	1.62	.883148	4.37	.116852
24	.783458	2.75	.900047	1.60	.883410	4.37	.116590
25	9.783623	2.75	9.899951	1.62	9.883672	4.37	0.116328
26	.783788	2.75	.899854	1.62	.883934	4.37	.116066
27	.783953	2.75	.899757	1.62	.884196	4.35	.115804
28	.784118	2.73	.899660	1.60	.884457	4.37	.115543
29	.784282	2.75	.899564	1.62	.884719	4.35	.115281
30	9.784447	2.75	9.899467	1.62	9.884980	4.37	0.115020
31	.784612	2.73	.899370	1.62	.885242	4.37	.114758
32	.784776	2.75	.899273	1.62	.885504	4.35	.114496
33	.784941	2.73	.899176	1.63	.885765	4.35	.114235
34	.785105	2.73	.899078	1.62	.886026	4.37	.113974
35	9.785269	2.73	9.898981	1.62	9.886288	4.35	0.113712
36	.785433	2.73	.898884	1.62	.886549	4.37	.113451
37	.785597	2.73	.898787	1.63	.886811	4.35	.113189
38	.785761	2.73	.898689	1.62	.887072	4.35	.112928
39	.785925	2.73	.898592	1.63	.887333	4.35	.112667
40	9.786089	2.72	9.898494	1.62	9.887594	4.35	0.112406
41	.786252	2.73	.898397	1.63	.887855	4.35	.112145
42	.786416	2.72	.898299	1.62	.888116	4.37	.111884
43	.786579	2.72	.898202	1.63	.888378	4.35	.111622
44	.786742	2.73	.898104	1.63	.888639	4.35	.111361
45	9.786906	2.72	9.898006	1.63	9.888900	4.35	0.111100
46	.787069	2.72	.897908	1.63	.889161	4.33	.110839
47	.787232	2.72	.897810	1.63	.889421	4.35	.110579
48	.787395	2.70	.897712	1.63	.889682	4.35	.110318
49	.787557	2.72	.897614	1.63	.889943	4.35	.110057
50	9.787720	2.72	9.897516	1.63	9.890204	4.35	0.109796
51	.787883	2.70	.897418	1.63	.890465	4.33	.109535
52	.788045	2.72	.897320	1.63	.890725	4.35	.109275
53	.788208	2.70	.897222	1.65	.890986	4.35	.109014
54	.788370	2.70	.897123	1.63	.891247	4.33	.10875
55	9.788532	2.70	9.897025	1.65	9.891507	4.35	0.10849
56	.788694	2.70	.896926	1.63	.891768	4.33	.10823
57	.788856	2.70	.896828	1.65	.892028	4.35	.10797
58	.789018	2.70	.896729	1.63	.892289	4.33	.10771
59	.789180	2.70	.896631	1.65	.892549	4.33	.10745
60	9.789342		9.896532		9.892810		0.1071[illegible]
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.789342	2.70	9.896532	1.65	9.892810	4.33	0.107190	60
1	.789504	2.68	.896433	1.63	.893070	4.35	.106930	59
2	.789665	2.70	.896335	1.65	.893331	4.33	.106669	58
3	.789827	2.68	.896236	1.65	.893591	4.33	.106409	57
4	.789988	2.68	.896137	1.65	.893851	4.33	.106149	56
5	9.790149	2.68	9.896038	1.65	9.894111	4.35	0.105889	55
6	.790310	2.68	.895939	1.65	.894372	4.33	105628	54
7	.790471	2.68	.895840	1.65	.894632	4.33	.105368	53
8	.790632	2.68	.895741	1.67	.894892	4.33	105108	52
9	.790793	2.68	.895641	1.65	.895152	4.33	.104848	51
10	9.790954	2.68	9.895542	1.65	9.895412	4.33	0.104588	50
11	.791115	2.67	.895443	1.67	.895672	4.33	.104328	49
12	.791275	2.68	.895343	1.65	.895932	4.33	.104068	48
13	.791436	2.67	.895244	1.65	.896192	4.33	.103808	47
14	.791596	2.68	.895145	1.67	.896452	4.33	.103548	46
15	9.791757	2.67	9.895045	1.67	9.896712	4.32	0.103288	45
16	.791917	2.67	.894945	1.65	.896971	4.33	.103029	44
17	.792077	2.67	.894846	1.67	.897231	4.33	.102769	43
18	.792237	2.67	.894746	1.67	.897491	4.33	.102509	42
19	.792397	2.67	.894646	1.67	.897751	4.32	.102249	41
20	9.792557	2.65	9.894546	1.67	9.898010	4.33	0.101990	40
21	.792716	2.67	.894446	1.67	.898270	4.33	.101730	39
22	.792876	2.65	.894346	1.67	.898530	4.32	.101470	38
23	.793035	2.67	.894246	1.67	.898789	4.33	.101211	37
24	.793195	2.65	.894146	1.67	.899049	4.32	.100951	36
25	9.793354	2.67	9.894046	1.67	9.899308	4.33	0.100692	35
26	.793514	2.65	.893946	1.67	.899568	4.32	.100432	34
27	.793673	2.65	.893846	1.68	.899827	4.33	.100173	33
28	.793832	2.65	.893745	1.67	.900087	4.32	.099913	32
29	.793991	2.65	.893645	1.68	.900346	4.32	.099654	31
30	9.794150	2.63	9.893544	1.67	9.900605	4.32	0.099395	30
31	.794308	2.65	.893444	1.68	.900864	4.33	099136	29
32	.794467	2.65	.893343	1.67	.901124	4.32	.098876	28
33	.794626	2.63	.893243	1.68	.901383	4.32	.098617	27
34	.794784	2.63	.893142	1.68	.901642	4.32	.098358	26
35	9.794942	2.65	9.893041	1.68	9.901901	4.32	0.098099	25
36	.795101	2.63	.892940	1.68	.902160	4.33	097840	24
37	.795259	2.63	.892839	1.67	.902420	4.32	.097580	23
38	.795417	2.63	.892739	1.68	.902679	4.32	097321	22
39	.795575	2.63	.892638	1.70	.902938	4.32	.097062	21
40	9.795733	2.63	9.892536	1.68	9.903197	4.32	0.096803	20
41	.795891	2.63	.892435	1.68	.903456	4.30	096544	19
42	.796049	2.62	.892334	1.68	.903714	4.32	.096286	18
43	.796206	2.63	.892233	1.68	.903973	4.32	.096027	17
44	.796364	2.62	.892132	1.70	.904232	4.32	095768	16
45	9.796521	2.63	9.892030	1.68	9.904491	4.32	0.095509	15
46	.796679	2.62	.891929	1.70	.904750	4.30	.095250	14
47	.796836	2.62	.891827	1.68	.905008	4.32	.094992	13
48	.796993	2.62	.891726	1.70	.905267	4.32	.094733	12
49	.797150	2.62	.891624	1.68	.905526	4.32	.094474	11
50	9.797307	2.62	9.891523	1.70	9.905785	4.30	0.094215	10
51	.797464	2.62	.891421	1.70	.906043	4.32	.093957	9
52	.797621	2.60	.891319	1.70	.906302	4.30	.093698	8
53	.797777	2.62	.891217	1.70	.906560	4.32	.093440	7
54	.797934	2.62	.891115	1.70	.906819	4.30	093181	6
55	9.798091	2.60	9.891013	1.70	9.907077	4.32	0.092923	5
56	.798247	2.60	.890911	1.70	.907336	4.30	.092664	4
57	.798403	2.62	.890809	1.70	.907594	4.32	.092406	3
58	.798560	2.60	.890707	1.70	.907853	4.30	.092147	
59	.798716	2.60	.890605	1.70	.908111	4.30	.091889	
60	9.798872		9.890503		9.908369		0.091631	
	Cos.	D. 1".	Sin.	D 1".	Cot.	D. 1".	Tan.	

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.798872	2.60	9.890503	1.72	9.908369	4.32	0.091631	60
1	.799028	2.60	.890400	1.70	.908628	4.30	.091372	59
2	.799184	2.58	.890298	1.72	.908886	4.30	.091114	58
3	.799339	2.60	.890195	1.70	.909144	4.30	.090856	57
4	.799495	2.60	.890093	1.72	.909402	4.30	.090598	56
5	9.799651	2.58	9.889990	1.70	9.909660	4.30	0.090340	55
6	.799806	2.60	.889888	1.72	.909918	4.32	.090082	54
7	.799962	2.58	.889785	1.72	.910177	4.30	.089823	53
8	.800117	2.59	.889682	1.72	.910435	4.30	.089565	52
9	.800272	2.58	.889579	1.70	.910693	4.30	.089307	51
10	9.800427	2.58	9.889477	1.72	9.910951	4.30	0.089049	50
11	.800582	2.58	.889374	1.72	.911209	4.30	.088791	49
12	.800737	2.58	.889271	1.72	.911467	4.30	.088533	48
13	.800892	2.58	.889168	1.73	.911725	4.28	.088275	47
14	.801047	2.57	.889064	1.72	.911982	4.30	.088018	46
15	9.801201	2.58	9.888961	1.72	9.912240	4.30	0.087760	45
16	.801356	2.58	.888858	1.72	.912498	4.30	.087502	44
17	.801511	2.57	.888755	1.73	.912756	4.30	.087244	43
18	.801665	2.57	.888651	1.72	.913014	4.28	.086986	42
19	.801819	2.57	.888548	1.73	.913271	4.30	.086729	41
20	9.801973	2.58	9.888444	1.72	9.913529	4.30	0.086471	40
21	.802128	2.57	.888341	1.73	.913787	4.28	.086213	39
22	.802282	2.57	.888237	1.72	.914044	4.30	.085956	38
23	.802436	2.55	.888134	1.73	.914302	4.30	.085698	37
24	.802589	2.57	.888030	1.73	.914560	4.28	.085440	36
25	9.802743	2.57	9.887926	1.73	9.914817	4.30	0.085183	35
26	.802897	2.55	.887822	1.73	.915075	4.28	.084925	34
27	.803050	2.57	.887718	1.73	.915332	4.30	.084668	33
28	.803204	2.55	.887614	1.73	.915590	4.28	.084410	32
29	.803357	2.57	.887510	1.73	.915847	4.28	.084153	31
30	9.803511	2.55	9.887406	1.73	9.916104	4.30	0.083896	30
31	.803664	2.55	.887302	1.73	.916362	4.28	.083638	29
32	.803817	2.55	.887198	1.75	.916619	4.30	.083381	28
33	.803970	2.55	.887093	1.73	.916877	4.28	.083123	27
34	.804123	2.55	.886989	1.73	.917134	4.28	.082866	26
35	9.804276	2.53	9.886885	1.75	9.917391	4.28	0.082609	25
36	.804428	2.55	.886780	1.73	.917648	4.30	.082352	24
37	.804581	2.55	.886676	1.75	.917906	4.28	.082094	23
38	.804734	2.53	.886571	1.75	.918163	4.28	.081837	22
39	.804886	2.55	.886466	1.73	.918420	4.28	.081580	21
40	9.805039	2.53	9.886362	1.75	9.918677	4.28	0.081323	20
41	.805191	2.53	.886257	1.75	.918934	4.28	.081066	19
42	.805343	2.53	.886152	1.75	.919191	4.28	.080809	18
43	.805495	2.53	.886047	1.75	.919448	4.28	.080552	17
44	.805647	2.53	.885942	1.75	.919705	4.28	.080295	16
45	9.805799	2.53	9.885837	1.75	9.919962	4.28	0.080038	15
46	.805951	2.53	.885732	1.75	.920219	4.28	.079781	14
47	.806103	2.52	.885627	1.75	.920476	4.28	.079524	13
48	.806254	2.53	.885522	1.77	.920733	4.28	.079267	12
49	.806406	2.52	.885416	1.75	.920990	4.28	.079010	11
50	9.806557	2.53	9.885311	1.77	9.921247	4.27	0.078753	10
51	.806709	2.52	.885205	1.75	.921503	4.28	.078497	9
52	.806860	2.52	.885100	1.77	.921760	4.28	.078240	8
53	.807011	2.53	.884994	1.75	.922017	4.28	.077983	7
54	.807163	2.52	.884889	1.77	.922274	4.27	.077726	6
55	9.807314	2.52	9.884783	1.77	9.922530	4.28	0.077470	5
56	.807465	2.50	.884677	1.75	.922787	4.28	.077213	4
57	.807615	2.52	.884572	1.77	.923044	4.27	.076956	3
58	.807766	2.52	.884466	1.77	.923300	4.28	.076700	2
59	.807917	2.50	.884360	1.77	.923557	4.28	.076443	1
60	9.808067		9.884254		9.923814		0.076186	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
2.52	9.884254	1.77	9.923814	4.27	0.076186	60
2.50	.884148	1.77	.924070	4.28	.075930	59
2.52	.884042	1.77	.924327	4.27	.075673	58
2.50	.883936	1.78	.924583	4.28	.075417	57
2.50	.883829	1.77	.924840	4.27	.075160	56
2.50	9.883723	1.77	9.925096	4.27	0.074904	55
2.50	.883617	1.78	.925352	4.28	.074648	54
2.50	.883510	1.77	.925609	4.27	.074391	53
2.50	.883404	1.78	.925865	4.28	.074135	52
2.50	.883297	1.77	.926122	4.27	.073878	51
2.48	9.883191	1.78	9.926378	4.27	0.073622	50
2.50	.883084	1.78	.926634	4.27	.073366	49
2.48	.882977	1.77	.926890	4.28	.073110	48
2.50	.882871	1.78	.927147	4.27	.072853	47
2.48	.882764	1.78	.927403	4.27	.072597	46
2.48	9.882657	1.78	9.927659	4.27	0.072341	45
2.48	.882550	1.78	.927915	4.27	.072085	44
2.48	.882443	1.78	.928171	4.27	.071829	43
2.48	.882336	1.78	.928427	4.28	.071573	42
2.48	.882229	1.80	.928684	4.27	.071316	41
2.48	9.882121	1.78	9.928940	4.27	0.071060	40
2.47	.882014	1.78	.929196	4.27	.070804	39
2.48	.881907	1.80	.929452	4.27	.070548	38
2.47	.881799	1.78	.929708	4.27	.070292	37
2.48	.881692	1.80	929964	4.27	070036	36
2.47	9.881584	1.78	9.930220	4.25	0.069780	35
2.47	.881477	1.80	.930475	4.27	.069525	34
2.47	.881369	1.80	.930731	4.27	.069269	33
2.47	.881261	1.80	.930987	4.27	.069013	32
2.47	.881153	1.78	.931243	4.27	.068757	31
2.47	9.881046	1.80	9.931499	4.27	0.068501	30
2.47	.880938	1.80	.931755	4.25	.068245	29
2.47	.880830	1.80	.932010	4.27	.067990	28
2.45	.880722	1.82	.932266	4.27	.067734	27
2.47	.880613	1.80	.932522	4.27	.067478	26
2.45	9.880505	1.80	9.932778	4.25	0.067222	25
2.47	.880397	1.80	.933033	4.27	.066967	24
2.45	.880289	1.82	.933289	4.27	.066711	23
2.45	.880180	1.80	.933545	4.25	.066455	22
2.45	.880072	1.82	.933800	4.27	.066200	21
2.45	9.879963	1.80	9.934056	4.25	0.065944	20
2.45	.879855	1.82	.934311	4.27	.065689	19
2.45	.879746	1.82	934567	4.25	.065433	18
2.45	.879637	1.80	.934822	4.27	.065178	17
2.43	.879529	1.82	.935078	4.25	.064922	16
2.45	9.879420	1.82	9.935333	4.27	0.064667	15
2.43	.879311	1.82	.935589	4.25	.064411	14
2.45	.879202	1.82	.935844	4.27	.064156	13
2.43	.879093	1.82	.936100	4.25	.063900	12
2.43	.878984	1.82	.936355	4.27	.063645	11
2.45	9.878875	1.82	9.936611	4.25	0.063389	10
2.43	.878766	1.83	.936866	4.25	.063134	9
2.43	.878656	1.82	.937121	4.27	.062879	8
2.42	.878547	1.82	.937377	4.25	.062623	7
2.43	.878438	1.83	.937632	4.25	.062368	6
2.43	9.878328	1.82	9.937887	4.25	0.062113	5
2.43	.878219	1.83	.938142	4.27	061858	4
2.42	.878109	1.83	.938398	4.25	.061602	3
2.43	.877999	1.82	.938653	4.25	.061347	2
2.42	.877890	1.83	.938908	4.25	.061092	1
	9.877780		9.939163		0.060837	0
D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	

M	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.816943	2.42	9.877780	1.83	9.939163	4.25	0.060837	60
1	.817088	2.42	.877670	1.83	.939418	4.25	.060582	59
2	.817233	2.43	.877560	1.83	.939673	4.25	.060327	58
3	.817379	2.42	.877450	1.83	.939928	4.25	.060072	57
4	.817524	2.40	.877340	1.83	.940183	4.27	.059817	56
5	9.817668	2.42	9.877230	1.83	9.940439	4.25	0.059561	55
6	.817813	2.42	.877120	1.83	.940694	4.25	.059306	54
7	.817958	2.42	.877010	1.85	.940949	4.25	.059051	53
8	.818103	2.40	.876899	1.83	.941204	4.25	.058796	52
9	.818247	2.42	.876789	1.85	.941459	4.23	.058541	51
10	9.818392	2.40	9.876678	1.83	9.941713	4.25	0.058287	50
11	.818536	2.42	.876568	1.85	.941968	4.25	.058032	49
12	.818681	2.40	.876457	1.83	.942223	4.25	.057777	48
13	.818825	2.40	.876347	1.85	.942478	4.25	.057522	47
14	.818969	2.40	.876236	1.85	.942733	4.25	.057267	46
15	9.819113	2.40	9.876125	1.85	9.942988	4.25	0.057012	45
16	.819257	2.40	.876014	1.83	.943243	4.25	.056757	44
17	.819401	2.40	.875904	1.85	.943498	4.23	.056502	43
18	.819545	2.40	.875793	1.85	.943752	4.25	.056248	42
19	.819689	2.38	.875682	1.85	.944007	4.25	.055993	41
20	9.819832	2.40	9.875571	1.87	9.944262	4.25	0.055738	40
21	.819976	2.40	.875459	1.85	.944517	4.23	.055483	39
22	.820120	2.38	.875348	1.85	.944771	4.25	.055229	38
23	.820263	2.38	.875237	1.85	.945026	4.25	.054974	37
24	.820406	2.40	.875126	1.87	.945281	4.23	.054719	36
25	9.820550	2.38	9.875014	1.85	9.945535	4.25	0.054465	35
26	.820693	2.38	.874903	1.87	.945790	4.25	.054210	34
27	.820836	2.38	.874791	1.85	.946045	4.23	.053955	33
28	.820979	2.38	.874680	1.87	.946299	4.25	.053701	32
29	.821122	2.38	.874568	1.87	.946554	4.23	.053446	31
30	9.821265	2.37	9.874456	1.87	9.946808	4.25	0.053192	30
31	.821407	2.38	.874344	1.87	.947063	4.25	.052937	29
32	.821550	2.38	.874232	1.85	.947318	4.23	.052682	28
33	.821693	2.37	.874121	1.87	.947572	4.25	.052428	27
34	.821835	2.37	.874009	1.88	.947827	4.23	.052173	26
35	9.821977	2.38	9.873896	1.87	9.948081	4.23	0.051919	25
36	.822120	2.37	.873784	1.87	.948335	4.25	.051665	24
37	.822262	2.37	.873672	1.87	.948590	4.23	.051410	23
38	.822404	2.37	.873560	1.87	.948844	4.25	.051156	22
39	.822546	2.37	.873448	1.88	.949099	4.23	.050901	21
40	9.822688	2.37	9.873335	1.87	9.949353	4.25	0.050647	20
41	.822830	2.37	.873223	1.88	.949608	4.23	.050392	19
42	.822972	2.37	.873110	1.87	.949862	4.23	.050138	18
43	.823114	2.35	.872998	1.88	.950116	4.25	.049884	17
44	.823255	2.37	.872885	1.88	.950371	4.23	.049629	16
45	9.823397	2.37	9.872772	1.88	9.950625	4.23	0.049375	15
46	.823539	2.35	.872659	1.87	.950879	4.23	.049121	14
47	.823680	2.35	.872547	1.88	.951133	4.25	.048867	13
48	.823821	2.37	.872434	1.88	.951388	4.23	.048612	12
49	.823963	2.35	.872321	1.88	.951642	4.23	.048358	11
50	9.824104	2.35	9.872208	1.88	9.951896	4.23	0.048104	10
51	.824245	2.35	.872095	1.90	.952150	4.25	.047850	9
52	.824386	2.35	.871981	1.88	.952405	4.23	.047595	8
53	.824527	2.35	.871868	1.88	.952659	4.23	.047341	7
54	.824668	2.33	.871755	1.90	.952913	4.23	.047087	6
55	9.824808	2.35	9.871641	1.88	9.953167	4.23	0.046833	5
56	.824949	2.35	.871528	1.90	.953421	4.23	.046579	4
57	.825090	2.33	.871414	1.88	.953675	4.23	.046325	3
58	.825230	2.35	.871301	1.90	.953929	4.23	.046071	2
59	.825371	2.33	.871187	1.90	.954183	4.23	.045817	1
60	9.825511		9.871073		9.954437		0.045563	0
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	M.

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.825511	2.33	9.871073	1.88	9.954437	4.23	0.045563	60
1	.825651	2.33	.870960	1.90	.954691	4.25	.045309	59
2	.825791	2.33	.870846	1.90	.954946	4.23	.045054	58
3	.825931	2.33	.870732	1.90	.955200	4.23	.044800	57
4	.826071	2.33	.870618	1.90	.955454	4.23	.044546	56
5	9.826211	2.33	9.870504	1.90	9.955708	4.22	0.044292	55
6	.826351	2.33	.870390	1.90	.955961	4.23	.044039	54
7	.826491	2.33	.870276	1.92	.956215	4.23	.043785	53
8	.826631	2.32	.870161	1.90	.956469	4.23	.043531	52
9	.826770	2.33	.870047	1.90	.956723	4.23	.043277	51
10	9.826910	2.32	9.869933	1.92	9.956977	4.23	0.043023	50
11	.827049	2.33	.869818	1.90	.957231	4.23	.042769	49
12	.827189	2.32	.869704	1.92	.957485	4.23	.042515	48
13	.827328	2.32	.869589	1.92	.957739	4.23	.042261	47
14	.827467	2.32	.869474	1.90	.957993	4.23	.042007	46
15	9.827606	2.32	9.869360	1.92	9.958247	4.22	0.041753	45
16	.827745	2.32	.869245	1.92	.958500	4.23	.041500	44
17	.827884	2.32	.869130	1.92	.958754	4.23	.041246	43
18	.828023	2.32	.869015	1.92	.959008	4.23	.040992	42
19	.828162	2.32	.868900	1.92	.959262	4.23	.040738	41
20	9.828301	2.30	9.868785	1.92	9.959516	4.22	0.040484	40
21	.828439	2.32	.868670	1.92	.959769	4.23	.040231	39
22	.828578	2.30	.868555	1.92	.960023	4.23	.039977	38
23	.828716	2.32	.868440	1.93	.960277	4.22	.039723	37
24	.828855	2.30	.868324	1.92	.960530	4.23	.039470	36
25	9.828993	2.30	9.868209	1.93	9.960784	4.23	0.039216	35
26	.829131	2.30	.868093	1.92	.961038	4.23	.038962	34
27	.829269	2.30	.867978	1.93	.961292	4.22	.038708	33
28	.829407	2.30	.867862	1.92	.961545	4.23	.038455	32
29	.829545	2.30	.867747	1.93	.961799	4.22	.038201	31
30	9.829683	2.30	9.867631	1.93	9.962052	4.23	0.037948	30
31	.829821	2.30	.867515	1.93	.962306	4.23	.037694	29
32	.829959	2.30	.867399	1.93	.962560	4.22	.037440	28
33	.830097	2.28	.867283	1.93	.962813	4.23	.037187	27
34	.830234	2.30	.867167	1.93	.963067	4.22	.036933	26
35	9.830372	2.28	9.867051	1.93	9.963320	4.23	0.036680	25
36	.830509	2.28	.866935	1.93	.963574	4.23	.036426	24
37	.830646	2.30	.866819	1.93	.963828	4.22	.036172	23
38	.830784	2.28	.866703	1.95	.964081	4.23	.035919	22
39	.830921	2.28	.866586	1.93	.964335	4.22	.035665	21
40	9.831058	2.28	9.866470	1.95	9.964588	4.23	0.035412	20
41	.831195	2.28	.866353	1.93	.964842	4.22	.035158	19
42	.831332	2.28	.866237	1.95	.965095	4.23	.034905	18
43	.831469	2.28	.866120	1.93	.965349	4.22	.034651	17
44	.831606	2.27	.866004	1.95	.965602	4.22	.034398	16
45	9.831742	2.28	9.865887	1.95	9.965855	4.23	0.034145	15
46	.831879	2.27	.865770	1.95	.966109	4.22	.033891	14
47	.832015	2.28	.865653	1.95	.966362	4.23	.033638	13
48	.832152	2.27	.865536	1.95	.966616	4.22	.033384	12
49	.832288	2.28	.865419	1.95	.966869	4.23	.033131	11
50	9.832425	2.27	9.865302	1.95	9.967123	4.22	0.032877	10
51	.832561	2.27	.865185	1.95	.967376	4.22	.032624	9
52	.832697	2.27	.865068	1.97	.967629	4.23	.032371	8
53	.832833	2.27	.864950	1.95	.967883	4.22	.032117	7
54	.832969	2.27	.864833	1.95	.968136	4.22	.031864	6
55	9.833105	2.27	9.864716	1.97	9.968389	4.23	0.031611	5
56	.833241	2.27	.864598	1.95	.968643	4.22	.031357	4
57	.833377	2.25	.864481	1.97	.968896	4.22	.031104	3
58	.833512	2.27	.864363	1.97	.969149	4.23	.030851	2
59	.833648	2.25	.864245	1.97	.969403	4.22	.030597	
60	9.833783		9.864127		9.969656		0.030344	
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.	

LOGARITHMIC SINES

M	Sin.	D. 1".	Cos	D. 1".	Tan.	D. 1".	Cot.
0	9.833783	2.27	9.864127	1.95	9.969656	4.22	0.0303
1	.833919	2.25	.864010	1.97	.969909	4.22	.0300
2	.834054	2.25	.863892	1.97	.970162	4.23	.0294
3	.834189	2.27	.863774	1.97	.970416	4.22	.0295
4	.834325	2.25	.863656	1.97	.970669	4.22	.0293
5	9.834460	2.25	9.863538	1.98	9.970922	4.22	0.02907
6	.834595	2.25	.863419	1.97	.971175	4.23	.02882
7	.834730	2.25	.863301	1.97	.971429	4.22	.02857
8	.834865	2.23	.863183	1.98	.971682	4.22	.02831
9	.834999	2.25	.863064	1.97	.971935	4.22	.02806
10	9.835134	2.25	9.862946	1.98	9.972188	4.22	.027812
11	.835269	2.23	.862827	1.97	.972441	4.23	.027559
12	.835403	2.25	.862709	1.98	.972695	4.22	.027305
13	.835538	2.23	.862590	1.98	.972948	4.22	.027052
14	.835672	2.25	.862471	1.97	.973201	4.22	.026799
15	9.835807	2.23	9.862353	1.98	9.973454	4.22	0.026546
16	.835941	2.23	.862234	1.98	.973707	4.22	.026293
17	.836075	2.23	.862115	1.98	.973960	4.22	.026040
18	.836209	2.23	.861996	1.98	.974213	4.22	.025787
19	.836343	2.23	.861877	1.98	.974466	4.23	.025534
20	9.836477	2.23	9.861758	2.00	9.974720	4.22	0.025280
21	.836611	2.23	.861638	1.98	.974973	4.22	.025027
22	.836745	2.22	.861519	1.98	.975226	4.22	.024774
23	.836878	2.23	.861400	2.00	.975479	4.22	.024521
24	.837012	2.23	.861280	1.98	.975732	4.22	.024268
25	9.837146	2.22	9.861161	2.00	9.975985	4.22	0.024015
26	.837279	2.22	.861041	1.98	.976238	4.22	.023762
27	.837412	2.23	.860922	2.00	.976491	4.22	.023509
28	.837546	2.22	.860802	2.00	.976744	4.22	.023256
29	.837679	2.22	.860682	2.00	.976997	4.22	.023003
30	9.837812	2.22	9.860562	2.00	9.977250	4.22	0.022750
31	.837945	2.22	.860442	2.00	.977503	4.22	.022497
32	.838078	2.22	.860322	2.00	.977756	4.22	.022244
33	.838211	2.22	.860202	2.00	.978009	4.22	.021991
34	.838344	2.22	.860082	2.00	.978262	4.22	.021738
35	9.838477	2.22	9.859962	2.00	9.978515	4.22	0.021485
36	.838610	2.20	.859842	2.02	.978768	4.22	.021232
37	.838742	2.22	.859721	2.00	.979021	4.22	.020979
38	.838875	2.20	.859601	2.02	.979274	4.22	.020726
39	.839007	2.22	.859480	2.00	.979527	4.22	.020473
40	9.839140	2.20	9.859360	2.02	9.979780	4.22	0.020220
41	.839272	2.20	.859239	2.00	.980033	4.22	.019967
42	.839404	2.20	.859119	2.02	.980286	4.20	.019714
43	.839536	2.20	.858998	2.02	.980538	4.22	.019462
44	.839668	2.20	.858877	2.02	.980791	4.22	.019209
	9.839800	2.20	9.858756	2.02	9.981044	4.22	0.018956
	.839932	2.20	.858635	2.02	.981297	4.22	.018703
	.840064	2.20	.858514	2.02	.981550	4.22	.018450
	.840196	2.20	.858393	2.02	.981803	4.22	.018197
	.840328	2.18	.858272	2.02	.982056	4.22	.017944
	9.840459	2.20	9.858151	2.03	9.982309	4.22	0.017691
	.840591	2.18	.858029	2.02	.982562	[illegible]	.017438
	.840722	2.20	.857908	2.03	.982814	4.22	.017186
	.840854	2.19	.857786	2.02	.983067	4.22	.016933
	.840985	2.18	.857665	2.03	.983320	4.22	.016680
	9.841116	2.18	9.857543	2.02	9.983573	4.22	0.016427
	.841247	2.18	.857422	2.03	.983826	4.22	.016174
	.841378	2.18	.857300	2.03	.984079	4.22	.015921
	.841509	2.18	.857178	2.03	.984332	4.20	.015668
	.841640	2.18	.857056	2.03	.984584	4.22	.015416
	.841771		9.856934		9.984837		0.015163
	Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.

M.	Sin.	D. 1".	Cos.	D. 1".	Tan.	D. 1".	Cot.	
0	9.841771	2.18	9.856934	2.03	9.984837	4.22	0.015163	60
1	.841902	2.18	.856812	2.03	.985090	4.22	.014910	59
2	.842033	2.17	.856690	2.03	.985343	4.22	014657	58
3	.842163	2.18	.856568	2.03	.985596	4.20	.014404	57
4	.842294	2.17	.856446	2.05	.985848	4.22	014152	56
5	9.842424	2.18	9.856323	2.03	9.986101	4.22	0.013899	55
6	.842555	2.17	.856201	2.05	.986354	4.22	013646	54
7	.842685	2.17	.856078	2.03	.986607	4.22	.013393	53
8	.842815	2.18	.855956	2.05	.986860	4.20	.013140	52
9	.842946	2.17	.855833	2.03	.987112	4.22	.012888	51
10	9.843076	2.17	9.855711	2.05	9.987365	4.22	0.012635	50
11	.843206	2.17	.855588	2.05	.987618	4.22	.012382	49
12	.843336	2.17	.855465	2.05	.987871	4.20	.012129	48
13	.843466	2.15	.855342	2.05	.988123	4.22	.011877	47
14	.843595	2.17	.855219	2.05	.988376	4.22	.011624	46
15	9.843725	2.17	9.855096	2.05	9.988629	4.22	0.011371	45
16	.843855	2.15	.854973	2.05	.988882	4.20	.011118	44
17	.843984	2.17	.854850	2.05	.989134	4.22	.010866	43
18	.844114	2.15	.854727	2.07	.989387	4.22	.010613	42
19	.844243	2.15	.854603	2.05	.989640	4.22	.010360	41
20	9.844372	2.17	9.854480	2.07	9.989893	4.20	0.010107	40
21	.844502	2.15	.854356	2.05	.990145	4.22	.009855	39
22	.844631	2.15	.854233	2.07	.990398	4.22	009602	38
23	.844760	2.15	854109	2.05	.990651	4.20	.009349	37
24	.844889	2.15	.853986	2.07	.990903	4.22	.009097	36
25	9.845018	2.15	9.853862	2.07	9.991156	4.22	0.008844	35
26	.845147	2.15	.853738	2.07	.991409	4.22	.008591	34
27	.845276	2.15	.853614	2.07	.991662	4.20	.008338	33
28	.845405	2.13	.853490	2.07	.991914	4.22	.008086	32
29	.845533	2.15	.853366	2.07	.992167	4.22	.007833	31
30	9.845662	2.13	9.853242	2.07	9.992420	4.20	0.007580	30
31	.845790	2.15	.853118	2.07	.992672	4.22	.007328	29
32	.845919	2.13	.852994	2.08	.992925	4.22	.007075	28
33	.846047	2.13	.852869	2.07	.993178	4.22	.006822	27
34	.846175	2.15	852745	2.08	.993431	4.20	.006569	26
35	9.846304	2.13	9.852620	2.07	9.993683	4.22	0.006317	25
36	.846432	2.13	852496	2.08	.993936	4.22	.006064	24
37	846560	2.13	.852371	2.07	.994189	4.20	.005811	23
38	.846688	2.13	852247	2.08	.994441	4.22	.005559	22
39	.846816	2.13	.852122	2.08	.994694	4.22	.005306	21
	9.846944	2.12	9.851997	2.08	9.994947	4.20	0.005053	20
	.847071	2.13	.851872	2.08	.995199	4.22	.004801	19
	.847199	2.13	.851747	2.08	.995452	4.22	.004548	18
	.847327	2.12	.851622	2.08	.995705	4.20	.004295	17
	.847454	2.13	.851497	2.08	.995957	4.22	.004043	16
	9.847582	2.12	9.851372	2.10	9.996210	4.22	0.003790	15
	.847709	2.12	.851246	2.08	.996463	4.20	.003537	14
	.847836	2.13	.851121	2.08	.996715	4.22	.003285	13
	.847964	2.12	.850996	2.10	.996968	4.22	.003032	12
	.848091	2.12	.850870	2.08	.997221	4.20	.002779	11
	9.848218	2.12	9.850745	2.10	9.997473	4.22	0.002527	10
	.848345	2.12	.850619	2.10	.997726	4.22	.002274	9
	.848472	2.12	.850493	2.08	.997979	4.20	.002021	8
	.848599	2.12	.850368	2.10	.998231	4.22	.001769	7
	848726	2.10	.850242	2.10	.998484	4.22	.001516	6
	9.848852	2.12	9.850116	2.10	9.998737	4.20	0.001263	5
	.848979	2.12	.849990	2.10	.998989	4.22	.001011	4
	.849106	2.10	.849864	2.10	.999242	4.22	.000758	
	.849232	2.12	.849738	2.12	.999495	4.20	.000505	
	.849359	2.10	.849611	2.10	.999747	4.22	.000253	
	849485		9.849485		0.000000		0.000000	
Cos.	D. 1".	Sin.	D. 1".	Cot.	D. 1".	Tan.		M.

TABLE 63. GIVING THE WEIGHTS OF DIFFERENT MATERIALS PE CUBIC FOOT[1]

MATERIAL	Weight per Cu. Ft.	
Ash timber	40	lbs.
Brick (pressed)	150	"
" (common building)	125	"
Cement (Portland)	75 to 90	"
" (Natural	50 to 56	"
Concrete 1 : 2 : 4 Mixture (Trap rock)	155	"
" (Gravel)	152	"
" (Limestone)	150	"
" (Sandstone)	145	"
" (Cinder)	110	"
" 1 : 3 : 6 Mixture (about 5 lbs. less)	—	"
Earth (common loam, loose and dry)	70	"
" (common loam, moist and rammed)	100	"
" (sand or gravel loose and dry)	100	"
" (sand or gravel rammed)	120	"
" (sand or gravel wet)	120	"
Hemlock timber	25	"
Hickory "	50	"
Iron (cast)	450	"
" (wrought)	480	"
Maple timber	50	"
Oak " (white)	48	"
" " (black)	40	"
Masonry (dressed granite or limestone)	165	"
" (mortar rubble)	155	"
" (dry ")	125	"
Pine (white)	25	"
" (northern yellow)	34	"
" (southern yellow)	40	"
Steel	490	"
Water	62.5	"

Miscellaneous Weights

1 bbl. Portland cement	376	lbs.
1 " natural "	235	"
1 gal. water "	8.345	"

[1] For weight of road rocks, see Tables 21 and 22, page 99.

Table 64. Giving Moduli of Elasticity, Working Stress and Ultimate Strength

Moduli of Elasticity

Material	Lbs. per Sq. In.
Concrete	2,000,000
Hemlock	900,000
Iron (cast)	17,500,000
Iron (wrought)	29,000,000
Oak	1,500,000
Pine (white)	1,600,000
Pine (yellow)	1,600,000
Steel (medium)	30,000,000
Spruce	1,600,000

Working Stresses in Lbs. per Square Inch

Material	Tension	Compression	Shear
Concrete	60	600	60 to 100
Hemlock	600	W. G.[1] 600 A. G.[2] 150	W. G. 100 A. G. 600
Iron (cast)	3,000	18,000	5,000
" (wrought)	10,000	8,000	8,000
Oak	1,200	W. G. 1,200 A. G. 500	W. G. 200 A. G. 1,000
Pine (white)	700	W. G. 700 A. G. 200	W. G. 100 A. G. 500
" (yellow)	1,200	W. G. 1,200 A. G. 350	W. G. 150 A. G. 1,250
Steel (medium)	12,000	12,000	12,000
Spuce	800	W G. 800 A. G. 200	W. G. 100 A. G. 750

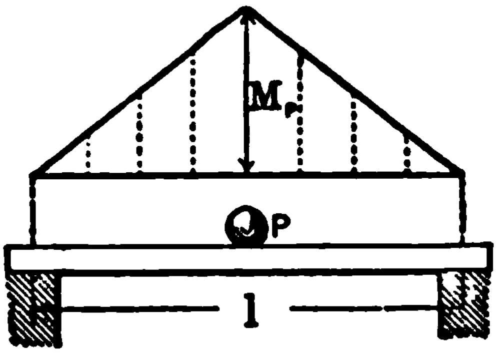
Ultimate Strength in Lbs. per Square Inch

Material	Tension	Compression	Shear
Concrete	300	3,000	1300
Hemlock	6,000	W. G. 6,000 A. G. 600	W. G. 350 A. G. 2,500
Iron (cast)	18,000	90.000	20,000 to 30,000
" (wrought)	50,000	40,000	35,000 to 55.000
Oak	12,000	W. G 7,000 A. G. 2,000	W. G. 800 A. G. 4.000
Pine (white)	7,000	W G. 5,500 A. G. 700	W. G 400 A. G 2,000
" (yellow)	12,000	W. G. 7,000 A. G. 1,400	W. G. 600 A. G. 5,000
Steel (medium)	60,000	60,000	50.000 to 70.000
Spruce	8,000	W. G. 6,000 A. G. 700	W. G. 400 A. G. 3.200

[1] W. G. — With Grain. [2] A. G. — Across Grain.

Table 65. Uniform Beams. Maximum Bending Moment and Deflections (Simple Cases)

Case 1. Beam with ends free. Single concentrated load P in middle of span; weight of beam disregarded.



Concentrated Load in Center of span

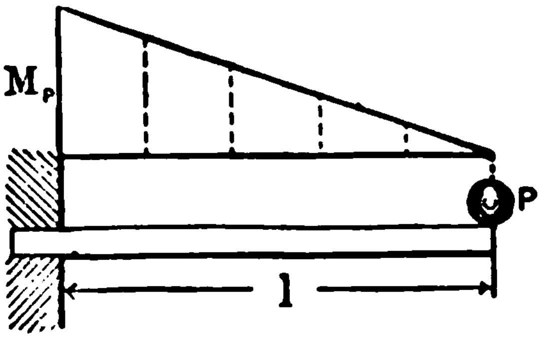
The maximum moment occurs at the center of the span.

$$M_p = \frac{Pl}{4}$$

The maximum deflection occurs at the center of the span.

$$D = \frac{Pl^3}{48\,EI}$$

Where D = the deflection in inches
P = load in pounds
l = span in inches
E = modulus of elasticity in lbs. per sq. inch
I = moment of inertia in inches^4
M_p = maximum moment in inch pounds.



Cantilever Beam

Case 2. Cantilever beam concentrated load P; weight of beam disregarded.

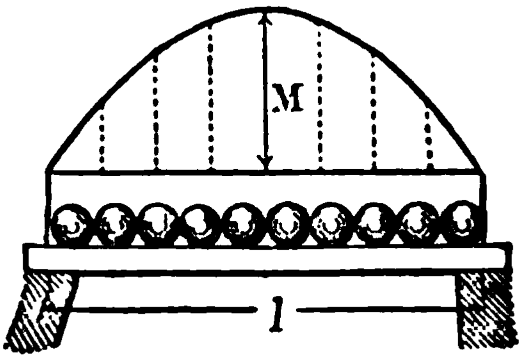
The maximum moment occurs at the support.

$$M_p = Pl$$

$$D = \frac{Pl^3}{3\,EI}$$

Case 3. Beam with ends free. Uniformly distributed load. The maximum moment occurs at the center of the span.

$$M = \frac{Wl}{8}$$



Uniform Load

The maximum deflection occurs at the center of the span.

$$D = \frac{5}{384}\,\frac{Wl^3}{EI}$$

In these formulæ W equals the total uniformly distributed load.

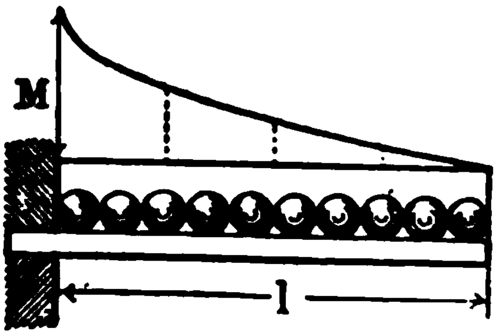
Case 4. Cantilever beam. Uniform load W.

Maximum moment occurs at the point of support.

$$M = \frac{Wl}{2}$$

The maximum deflection occurs at the free end.

$$D = \frac{Wl^3}{8\,EI}$$

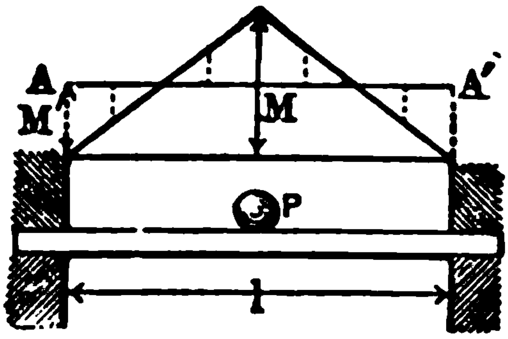


Case 5. Beam with fixed ends, concentrated load P in center of span; weight of beam disregarded.

The maximum bending moment occurs at the points of support and at the middle of the beam.

$$M = \frac{Pl}{8}$$

$$D = \frac{Pl^3}{192\,EI}$$



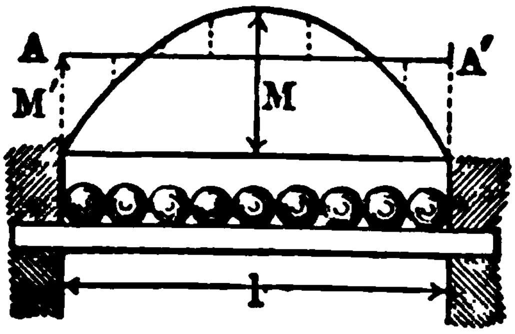
Case 6. Beam with fixed ends and a uniformly distributed load. Maximum bending moment occurs at the supports.

$$M' = \frac{Wl}{12}$$

$$M = \frac{Wl}{24}$$

Maximum deflection

$$= \frac{Wl^3}{384\,EI}$$



Resisting Moment of a beam is expressed by the formula

$$M_r = \frac{pI}{e}$$

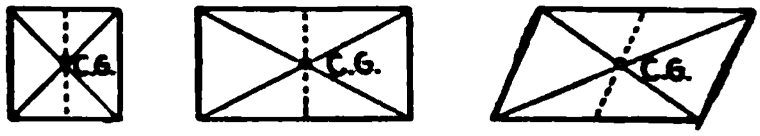
Where M_r = moment of resistance in inch pounds

p = maximum allowable fiber stress in lbs. per sq. inch.

I = moment of inertia of the beam in inches^4

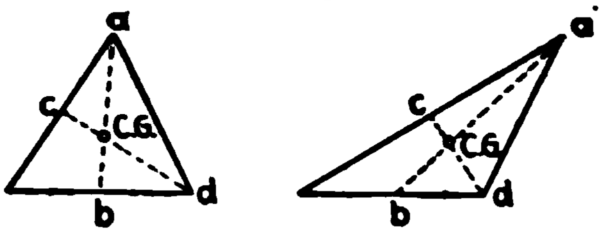
e = distance in inches from the neutral axis to the outer fiber

TABLE 66. CENTERS OF GRAVITY OF ORDINARY PLANE FIGURES



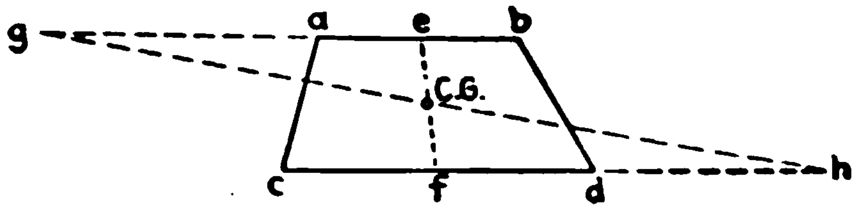
Squares, rectangles, parallelograms. Center of gravity is at the intersection of the diagonals or midway between the bases on a line drawn between the centers of those bases.

Triangles



Center of gravity is at the intersection of the medial lines $a\,b$ and $c\,d$; a medial line is a line drawn from any apex to the middle of the opposite side The distance $b\,(C.\,G.) = \frac{1}{3}\,a\,b$; that is, the center of gravity is on the medial line $\frac{1}{3}$ of the distance from the base to the apex.

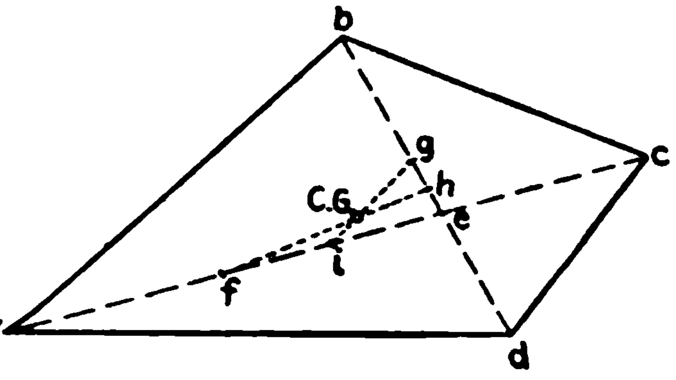
Trapezoid



Graphic Method. Prolong $b\,a$ to g, making $a\,g = c\,d$. Prolong $c\,d$ to h, making $d\,h = a\,b$. Connect $g\,h$. Bisect $a\,b$ at e. Bisect $c\,d$ at f. Connect $e\,f$: the intersection of $g\,h$ and $e\,f$ is the center of gravity.

The distance $f\,(C.G.) = \frac{ef}{3} \times \frac{2\,ab + cd}{ab + cd}$

Any Quadrilateral



Graphic Method. Draw the diagonals $a\,c$ and $b\,d$ intersecting at e.

Lay off $a\,f = e\,c$

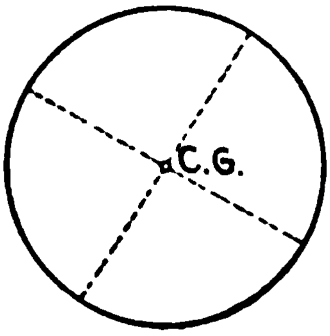
Lay off $b\,g = e\,d$

Bisect $e\,g$ at h; bisect $e\,f$ at i.

The intersection of $f\,h$ and $g\,i$ is the center of gravity of the figure.

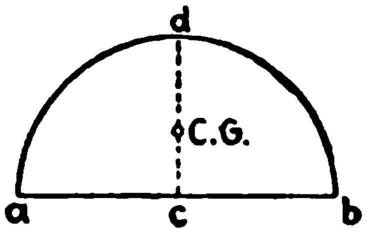
Circles

Center of gravity at the center



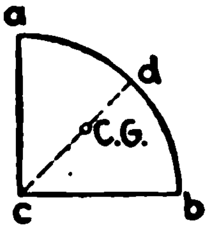
Semicircle

The center of gravity lies on the radius perpendicular to the diameter. The distance c ($C.G.$) = radius × 0.4244



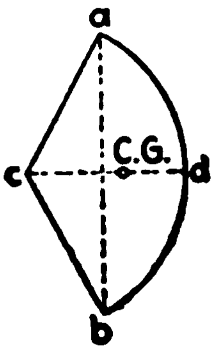
Quadrant

The center of gravity lies on the radius which bisects the $\angle\ acb$. The distance c ($C.G.$) = radius × 0.6002



Sector

The center of gravity lies on the radius bisecting the $\angle\ acb$. The distance c ($C.G.$) = $\frac{2}{3}$ radius × $\frac{\text{chord } ab}{\text{arc } adb} = \frac{\text{radius}^2 \times \text{chord}}{3 \times \text{area}}$



Segment

The center of gravity lies on the perpendicular erected at the center of the chord ab.

The distance c ($C.G.$) = $\frac{\text{chord } ab^3}{12 \times \text{area of segment}}$

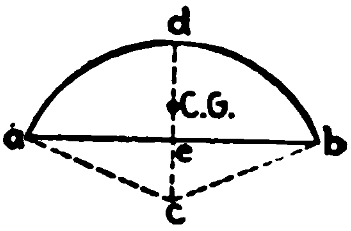
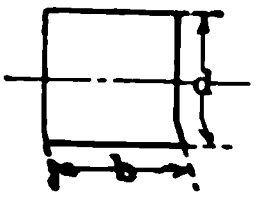
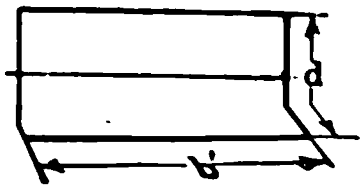


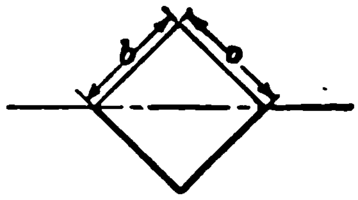
Table 67. Moments of Inertia of Simple Sections

I = Moment of Inertia

$$I = \frac{bd^3}{12}$$

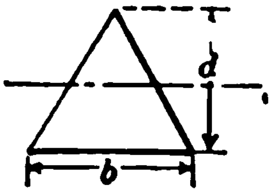






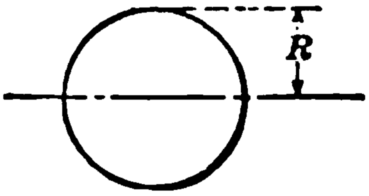
Square

$$I = \frac{b^4}{12}$$



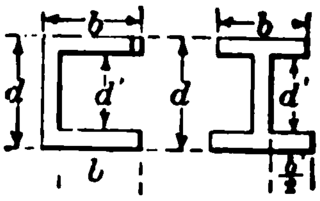
Triangles

$$I = \frac{bd^3}{36}$$



Circles

$$I = 0.7854\,R^4$$



$$I = \frac{bd^3 - b'd'^3}{12}$$

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NOTES